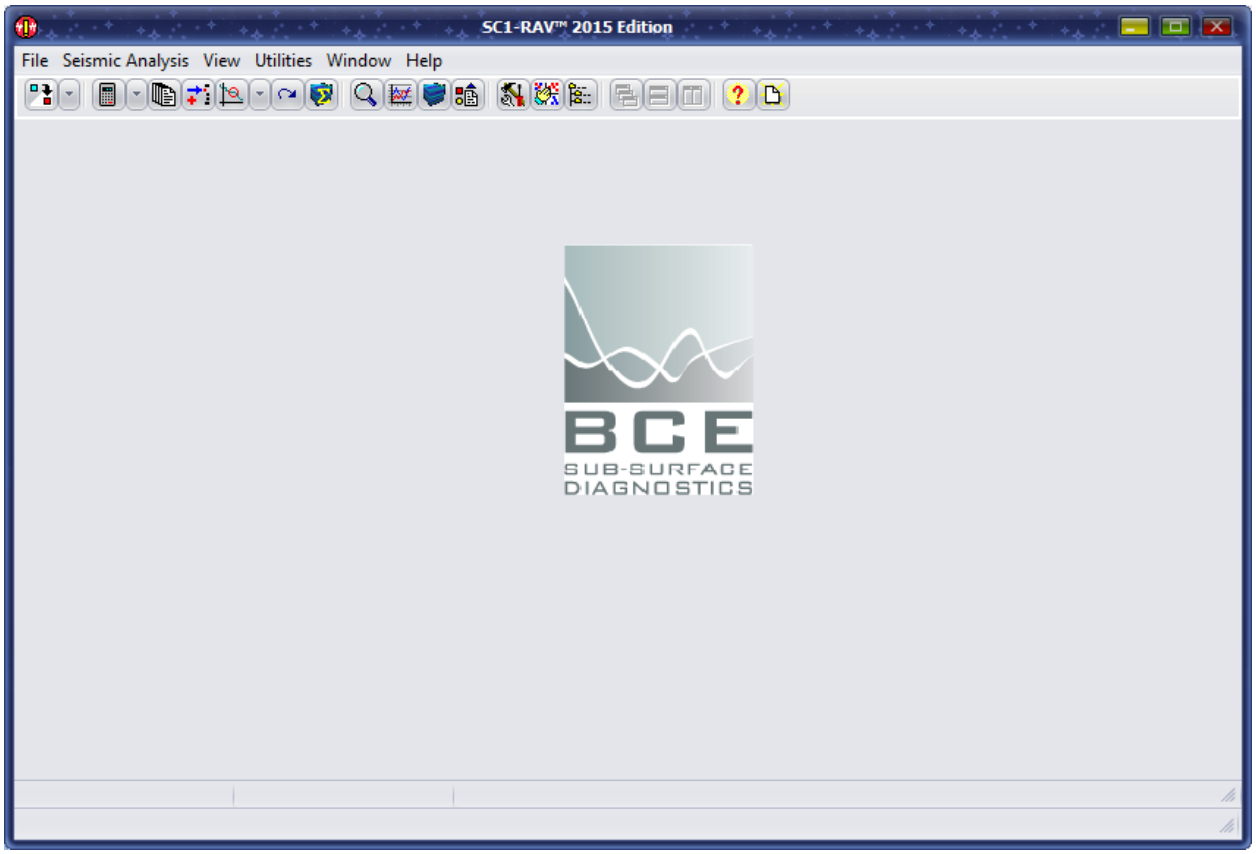
# SC1-RAV™ 2015

## User's Reference Manual

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*The company provides state-of-the-art hardware and software solutions for a wide variety of seismic engineering applications. If necessary, we will customize our products to suit the requirements of our clients even better.*

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- Seismic Data Acquisition and Signal Conditioning Hardware
- Seismic Data Processing Software
- Applied Seismology Consulting Services
- Seismic Data Processing
- Professional Seminars

*By publishing this manual we will hopefully provide a better understanding of downhole seismic testing and the role it can play in geotechnical investigations.*

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- **ability to apply notch filter on harmonics within the Cascadable Filters**
- **enhanced display options when viewing seismic data and displaying standard VSPs or full waveform VSPs**
- **option to save or export user specified arrival times when displaying standard VSPs and to display previously saved arrival times when displaying standard VSPs**

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# Chapter 1 Introduction

## *1.1 What is SC1-RAV™?*

***SC1-RAV™*** is a Windows® program, which facilitates comprehensive Downhole Seismic Testing (DST) data reduction, analysis, and display. The user is provided with an extensive set of mathematical tools and patented algorithms to derive DST interval velocities and to quantify vertical seismic profiles. In addition, ***SC1-RAV™*** allows the review of frequency spectra, the comparison of both unfiltered and digitally filtered traces, and the plotting of interval velocity profiles. ***SC1-RAV™*** also provides extensive chart editing, plotting, and exporting functionality.

***SC1-RAV™*** includes the following features:

- Configurable for either geophones or accelerometers.
- Extensive frequency spectrum analysis.
- Bandpass, high pass, low pass, and notch digital filters.
- Patented P-Wave and S-wave velocity estimation algorithm.
- Batch job processing.
- Source wave arrival time estimation.
- Linear least squares regression interval velocity estimation.
- Reverse Polarity Technique.
- Forward Modeling Downhill Simplex Method (FMDSM) in estimating interval velocities.
- Display of Vertical Seismic Profiles (VSPs) with trend line specification.
- Ability to save or export user specified arrival times when displaying standard VSPs.
- Display of peak particle accelerations, velocities, and displacements.
- 3D Displays of VSPs.
- Calculation of interval Gmax values.
- The ability to carry out data interpolation to increase the time series resolution.
- Post data stacking.
- Application of a signal decay function to minimize the effect of source wave multiples.
- Display of calculated interval velocities.

## *1.2 Organization of users manual*

The purpose of this manual is to instruct users of ***SC1-RAV™*** in the use of the program by explaining its structure, taking the user step by step through the program menus, and specifying the use of interactive graphics and I/O routines.

In addition, the manual contains the following items:

- Appendix 1 provides a copy of the paper entitled "Digital filtering techniques for interpreting seismic cone data." This paper outlines the mathematical technique utilized in obtaining optimal cross-correlation time shifts.
- Appendix 2 provides a copy of the paper entitled "Derivation of seismic cone interval velocities utilizing forward modeling and the downhill simplex method". This paper outlines the mathematical algorithms utilized in the Forward Modeling and the Downhill Simplex Method (FMDSM).

If required, BCE can also provide a thorough training course in the use of the ***SC1-RAV™*** software package. Alternatively, the user can contact BCE to obtain a step-by-step instructional document that outlines the estimation of interval velocities utilizing the ***SC1-RAV™*** software. The methods of analysis covered range from basic trend line estimation to more advanced patented cross-correlation techniques and iterative forward modeling. The user is also provided with an exercise document and associated seismic data set

# Chapter 2 Main Menu and Tool Bar

## 2.1 Introduction

***SC1-RAV™*** is a Windows® program utilizing time series analysis and interactive graphics for the purpose of estimating shear and pressure wave interval velocities. The main menu of ***SC1-RAV™,*** as shown in Figure 1, has six different options:

- *File*
- *Seismic Analysis* (as described in Chapter 3 of this manual)
- *View* (as described in Chapter 4 of this manual)
- *Utilities* (as described in Chapter 5 of this manual)
- *Window* (as described in Chapter 7 of this manual)
- *Help*.

The desired option is chosen either by moving the mouse over the desired option and pressing the left hand mouse button, by pressing function <F10> on the keyboard and selecting the desired highlighted option, or by pressing the corresponding underlined menu item letter on the keyboard.

The program can also be operated by clicking on icons. The toolbar of ***SC1-RAV™***, as illustrated in Figure 1, consists of 19 different icons:

- *Convert data into SC1-RAV™ format*

- *Calculate Interval Velocity*
- *Apply Data Stack*
- *Apply Data Interpolation*
- *Apply Signal Decay*
- *Change Polarity*
- *Calculate Shear Modulus*

- *View Seismic Data*
- *Display VSP*
- *3D Display*
- *Display Interval Velocities*

- *Default GUI Settings*
- *Specify Sensor Type and Units*
- *Sort SH Data Files and Create Working Directories*

- *Cascade*
- *Tile Horizontally*
- *Tile Vertically*

- *About*
- *Open User's Manual*

***Figure 1: Main Menu and Tool Bar in SC1-RAV™***

## 2.2 File Submenu Options

The File option provides the user with 2 options:

- *Convert Geotech AB data*
- *Exit*

The *Convert Geotech AB Data* option allows the user to select a set of SCPT data files acquired with a standard uniaxial Geotech AB system and to convert these into the *SC1-RAV™* data format for processing as follows:

1. optionally, enter/update desired site information selecting the *Site Info Specification* button (see Figure 3).
2. specify the set of files to be converted by clicking on the *Specify Files* button, which opens a *File Input* dialog box as shown in Figure 6.
3. click on *Open* button at the bottom of this dialog box to convert each individual file into the *SC1-RAV™* data file format. The program then copies the converted Geotech data files into subdirectory ..\BCEFORMAT that is created in the same directory as the original. The converted data files have extension '_BCE' appended to the original file name.

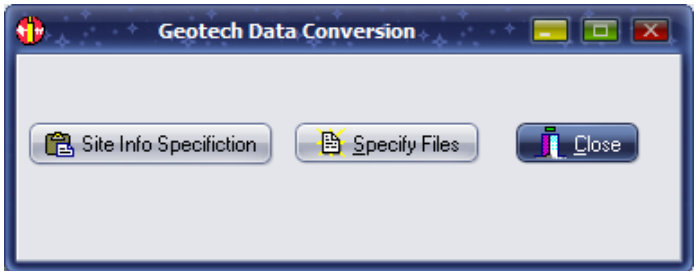



***Figure 2: Geotech Data Conversion dialog box***

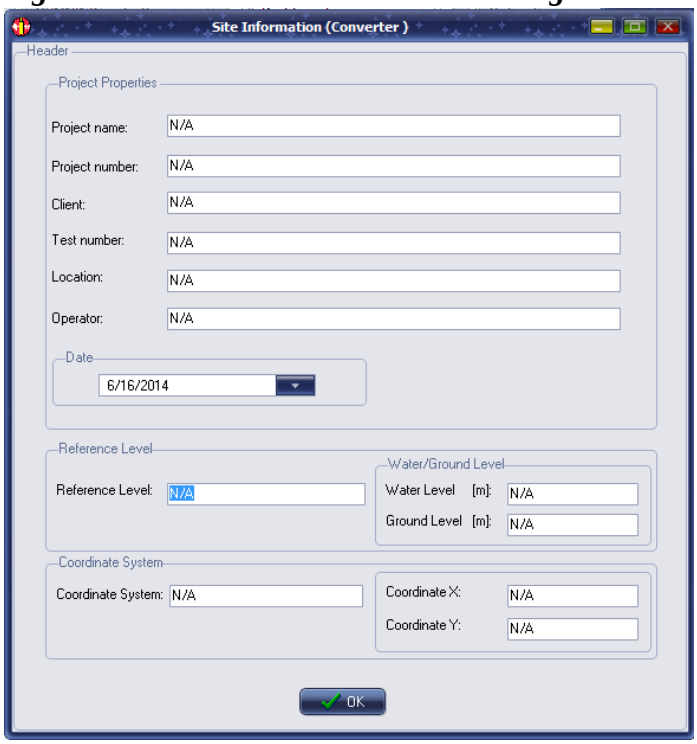



***Figure 3: Site Information dialog box***

# Chapter 3 Seismic Analysis

The *Seismic Analysis*[1] menu option allows the user to process acquired seismic traces so that important geotechnical design parameters are obtained. As shown in Figure 4, this menu[1] has six different options:

- *Calculate Interval Velocities*
- *Apply Data Stack*
- *Apply Data Interpolation*
- *Apply Signal Decay*
- *Change Polarity*
- *Calculate Shear Modulus*

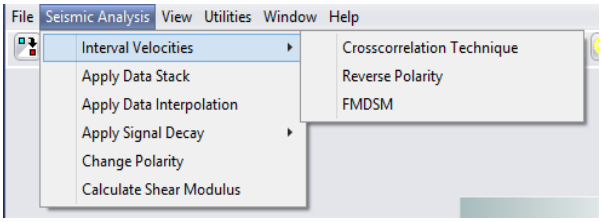



***Figure 4: Interval Velocities submenu with corresponding analysis options***

In this menu the user specifies the desired option by selecting the appropriate graphical tabs or corresponding toolbar icon.

## *3.1 Calculate Interval Velocities*

When selecting the *Calculate Interval Velocities* option in the S*eismic Analysis* menu, a submenu as shown in Figure 4 appears. This submenu allows the user to select one of three available algorithms to derive Downhole Seismic Testing (DST) interval velocities:

- *the Cross-correlation Technique*
- *the Reverse Polarity Technique*
- *the Forward Modeling Downhill Simplex Method* (FMDSM).

[1] The *Sensor Type* (geophone or accelerometer) should be specified prior to the implementation of the options under *Seismic Analysis*. Section 5.2 outlines the *Sensor Type and Units* menu and corresponding interface.

### 3.1.1 Cross-correlation Technique

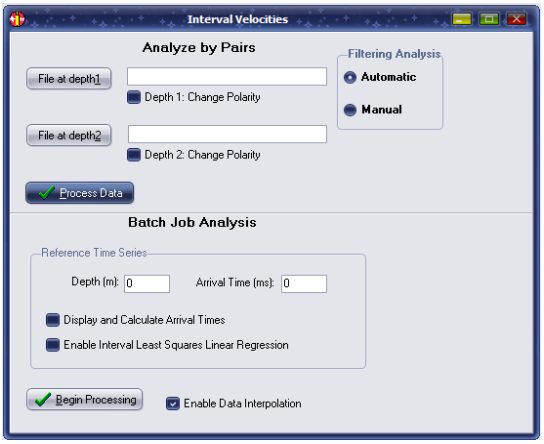



***Figure 5: Crosscorrelation Technique Interval Velocities dialog box***

The *Cross-correlation Technique* implements a patented mathematical algorithm to derive DST interval velocity profiles based on cross correlating the wave recorded at consecutive depth increments (Baziw 1993). The value of the time shift at the maximum cross-correlation value is assumed to be the relative travel time difference for the wave to travel the depth increment. This technique has the following advantages over the standard Reverse Polarity Technique:

- it minimizes the human bias associated with visually selecting a crossover point in deriving interval times which is required by the reverse polarity technique.
- it utilizes the full waveform in deriving interval travel times as opposed to a single point.
- the correlation coefficient between the two waves gives the user an indication of the similarity between the two waves being correlated and the subsequent accuracy of the velocity estimate.

  **Note:**

  **Enabling check box *Enable Data Interpolation* enhances the resolution of the optimized correlator by utilizing linear interpolation between digitally sampled points, guaranteeing a minimal time resolution of 0.01 ms (equivalent sampling rate of 100 KHz).**
- it obtains two independent velocity estimates for each depth increment by comparing source wave generated on both the right and left side of the seismic probe.

Figure 5 shows the dialog box which appears when the *Cross-correlation Technique* analysis option is selected.

#### *3.1.1.1 Analyze by Pairs*

The *Analyze by Pairs* option under the *Cross-correlation Technique* refers to processing two seismic traces at a time at different depth increments in order to derive the seismic interval velocities. Referring to Figure 5, running this option requires the specification of the input file at depth 1 and another file at depth 2.

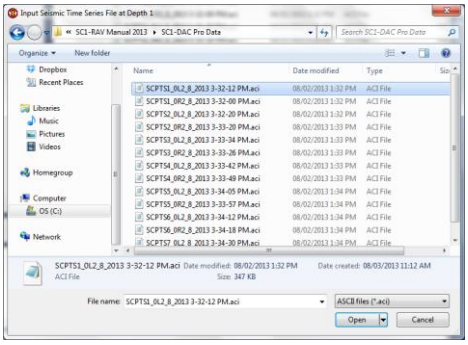


***Figure 6: File Input dialog box***

Figure 6 illustrates the dialog box for inputting these seismic data files. It is very important that these files correspond to the depths of penetration where depth2 is greater than depth1. In addition the sampling rate for the two traces must be the same and they should both be equivalently polarized. However, enabling check box *Depth (1-2): Change Polarity* allows for inverting

(flipping) data in a specific file.
The *Analysis by Pairs* can be done either *Automatically* or *Manually*, as explained in Sections 3.1.1.1.1 and 3.1.1.1.2 respectively, and the user should specify the desired processing method. Once the seismic files are inputted and the type of analysis is specified, the *Begin Processing* button is selected.

### 3.1.1.1.1 Automatic Processing

The *Automatic Processing* option refers to processing the in-situ seismic data without displaying frequency spectra and filtered traces. **This option saves substantial computing time, but is only applicable if the user has insight into the frequency spectrum of the seismic waves of interest.** It will use the sampling rate specified when the data is acquired, and will automatically reduce the seismic traces, calculate and display the corresponding velocity, accuracy and relative time shift.

When the Process Data button is selected the Cascadable Filters dialog box appears (see Figure 7). The cascadable filters are digital zero phase shift eighth order bandpass, notch, high, and low pass frequency filters. The user enables a filter by checking the *Enabled* box and specifying the appropriate frequency or frequencies (see b. below).

***Figure 7: Cascadable Filters dialog box***

a. Specify Start Time (T0)

The *Start Time* parameter refers to removing seismic responses dominated by high impact amplitudes and high bandwidth signals traveling down the borehole or seismic cone (SC) rods. This phenomenon can occur if the seismic source is close to the borehole or SC rods. Figure 8 illustrates this high impact energy phenomenon. It is sometimes not possible to filter these high impact signals with digital filters alone, and therefore the user is instructed to specify the time after impact signal so that these responses can be removed prior to digital filtering. For example, referring to Figure 8 the user would specify a T0 value of approximately 23 ms.

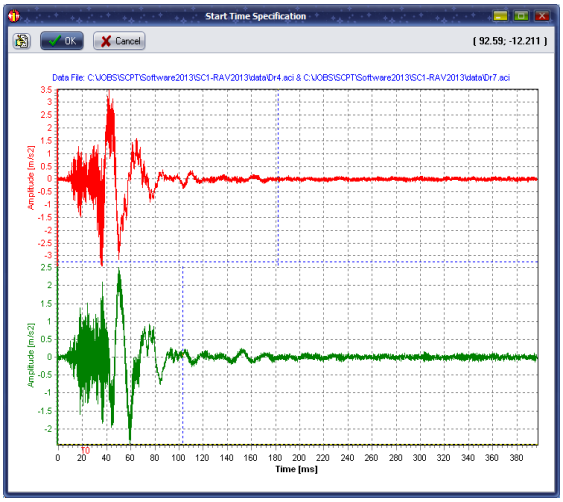



***Figure 8: Illustration of high impact amplitudes and high bandwidth signals due to rod noise***

b. Specify Filter Parameters

The program offers four different types of digital frequency filters:

- *Bandpass Filter*, where the user specifies the desired upper and lower cut-off frequencies.
- *Notch Filter*, where the user specifies the desired notch frequency
- *Low Pass Filter*, where the user specifies the desired low pass frequency.
- *High Pass Filter*, where the user specifies the desired high pass frequency

In each of these cases, default values, which are good starting points for inexperienced users, have already been entered, but these values can obviously be changed.
Generally, the only frequency filter required is either the bandpass filter or the low pass filter. For the bandpass filter both the low pass and high pass frequency must be specified to define the bandpass that isolates the seismic wave being reviewed. Typically, these values are set at 30 Hz and 120 Hz to 140 Hz, respectively for a SH-wave analysis. For the low pass filter the cutoff frequency is normally set between 120 and 140 Hz. The notch filter option is provided so that the user may remove unwanted frequencies, such as those due to power supplies (e.g. 60 or 120Hz) or electrical transmission line effects (and by checking the *Remove Harmonics* box the program will also remove frequencies equal to double and triple the frequency specified from the seismic trace). If the band of frequencies desired is too narrow or wide, then a set of cascadable low pass and high pass frequency filters can be utilized.

Next the user implements the specified filter parameters by checking the *Enabled* box and then pressing the *OK* button located at the bottom center of the *Cascade Filters* dialog box.

c. Calculate Velocity, Accuracy, and Relative Arrival Time Estimates

Once the *OK* button has been pushed, the program provides the user with the velocity, cross-correlation coefficient and relative arrival time estimates as shown in Figure 9. The relative arrival time estimates can subsequently be utilized within the *FMDSM technique* described in Section 3.1.3. The user can re-specify the calculated Time Shifts for the output of Automatic Interval Velocities and Manual Interval Velocities (by overwriting the values in the table shown in Figure 9) and subsequently re-calculate the interval velocities by selecting the calculator push button shown at the bottom of Figure 9.

The cross-correlation coefficient (CCC) gives an indication of how closely the correlated filtered seismic traces resemble each other and the reliability of the subsequent velocity estimate. The value of the CCC is between 0.0 and 1.0, and should be as close to 1.0 as possible. Values above 0.85 are recommended for the hammer shear source (i.e., SH-wave source).

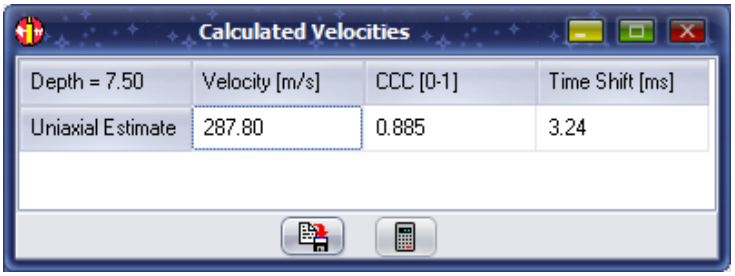



***Figure 9: Velocity, Cross-correlation Coefficient, and Time Shift Estimates***

d. Store Data

Storing the results can be done by pushing the button with the *Data Storage* icon shown at the center bottom of Figure 9. If the user decides to do so a window opens (as shown in Figure 10) in which the name of the output file can be defined by pressing icon or manually specifying the output file within the text box provided. If necessary, site information can be added or amended by clicking on the *Site Info Specification* button, which opens the window shown in Figure 11.

After the Output File has been specified the user selects push buttons *Save* or *Re-write*. If the user selects button *Re-write* and the file already exists, then the file will be re-written with the newly processed data. If the *Save* button is selected and the output file already exists, the velocity estimates will be appended to the data file.

Figure 12 shows a typical output data file. Depending on which filters are enabled, the applicable filter frequencies are stored within the output file.

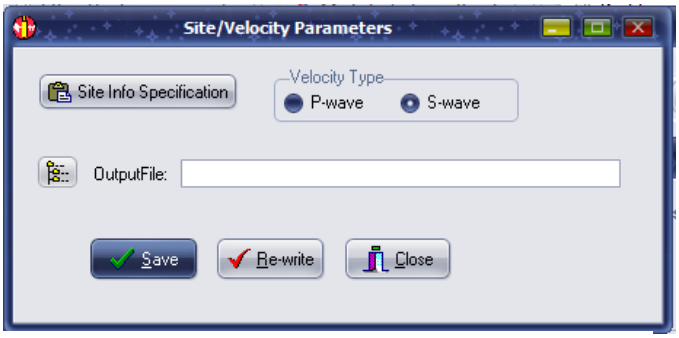



***Figure 10: Save Velocity Data dialog box***

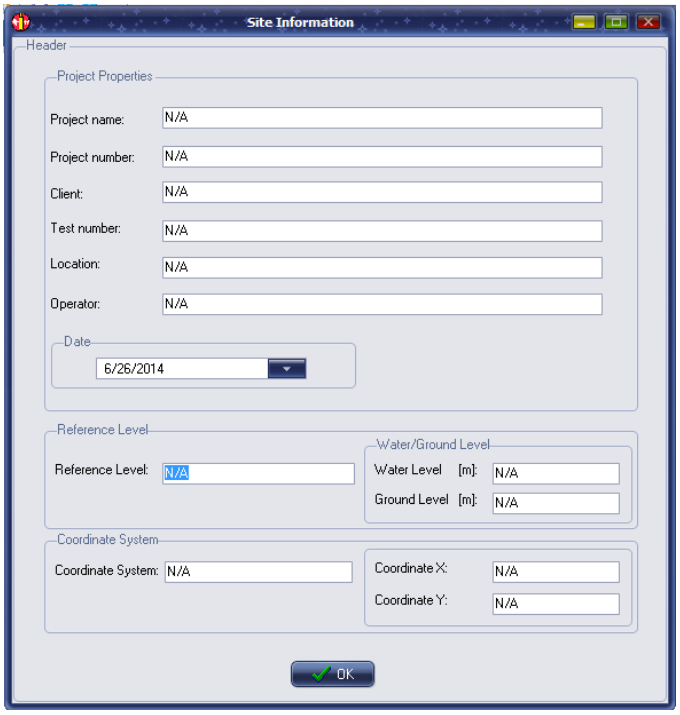



***Figure 11: SCPT Site Information dialog box***

2014
Project Name: Manual \ ProjectNumber: 001 \ Client: BCE
Test Number: 1 \ Location: Vancouver office \ Site Operator: GV \ Site Date: 6/26/2015 11:21:43 AM
Coordinate System: N/A \ Coordinate X: N/A \ Coordinate Y: N/A
Reference Level: N/A \ Water Level: N/A \ Ground Level: N/A

| Velocity (m/sec) | Type | Depth1 (m) | Depth2 (m) | Accuracy | Bandpass (Hertz) | TS (ms) |
|---|---|---|---|---|---|---|
| 119.50 | S | 1.00 | 2.00 | 0.997 | 30.0 to 100.0 | 4.96126.03 |

***Figure 12: Typical output file***

### 3.1.1.1.2 Manual Processing

The *Manual Processing* option is a more detailed analysis of the in-situ seismic traces. In this option, a start time is specified if desired, the inputted waves are then analyzed for frequency content, after which the filtered and unfiltered traces are displayed in order to decide whether the correct seismic waves were isolated. Finally the cross-correlation function is displayed followed by the velocity, accuracy and time shift estimates.

In the *Manual Processing* option the seismic traces are more thoroughly analyzed with interactive graphics. These graphics facilitate choosing the proper frequency filters to be used in the *Automatic Filtering* and *Batch Processing* options. For illustrative purposes, an example of data processed with ***SC1-RAV™*** using the *Manual Processing* option will be presented.
In this example data files Ds4.aci and Ds7.aci are analyzed, and the relevant parameters describing these digital seismic traces are as follows:

**Ds4.aci:**
Sampling rate: 0.1 *ms*
Depth: 2.7 *m*
X offset: 2.1 *m*
Y offset: 0.0 *m*

**Ds7.aci:**
Sampling rate: 0.1 *ms*
Depth: 3.7 *m*
X offset: 2.1 *m*
Y offset: 0.0 *m*

The message shown in Figure 13 appears when the user selects the *Process Data* button in the Cross-correlation Technique dialog box (see Figure 5) with the *Manual Processing* option enabled. By selecting push button *Yes* in Figure 13, then the output illustrated in Figure 14 appears; if push button *No* is selected, the program will move to the Spectral Analysis as shown in Figure 15.

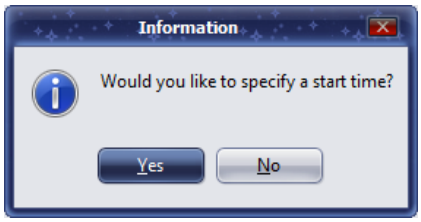



***Figure 13: Start time specification message dialog box***

In Figure 14 the seismic traces to be analyzed (i.e., DR4.aci and DR7.aci) are displayed. The cross-hair displayed in chart window is moved around by the mouse, with the corresponding time displayed in *ms* at the top of the chart. The time window can be zoomed into a desired range by pressing the left mouse button and moving the mouse left to right. The seismic traces are shifted left to right by pressing the right mouse button and moving the mouse. The user can zoom out again by pressing the left mouse button and moving the mouse right to left. The start time, T0, is selected by pressing the middle mouse button or <Shift> + right or left mouse buttons. The selected Start Time T0 can be cleared by double clicking on the left mouse button. The grey chart spacer allows the user to expand or contract the individual charts as desired. Once the

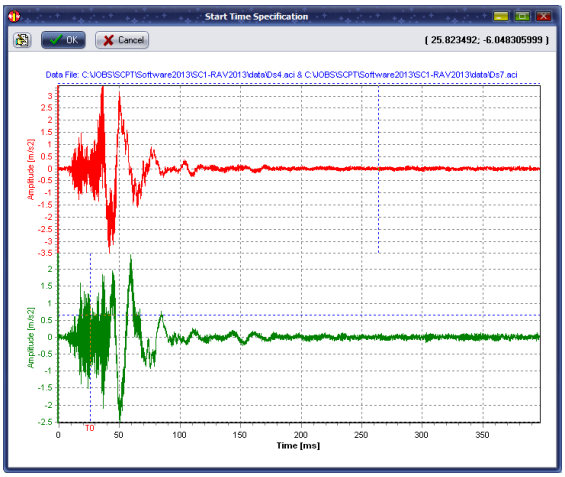



***Figure 14: Graphically specifying the start time parameter***

start time has been defined by clicking on the *OK* button at the top left of Figure 14 the program will move to the Spectral Analysis as shown in Figure 15.

Figure 15 shows the DS4.aci seismic trace and its corresponding frequency spectrum. The cross-hair displayed in the frequency spectrum and time series is moved around by the mouse, with the corresponding frequency and time displayed above the charts. The frequency spectrum and time series can be zoomed into a desired range by pressing the left mouse button and moving the mouse left to right.

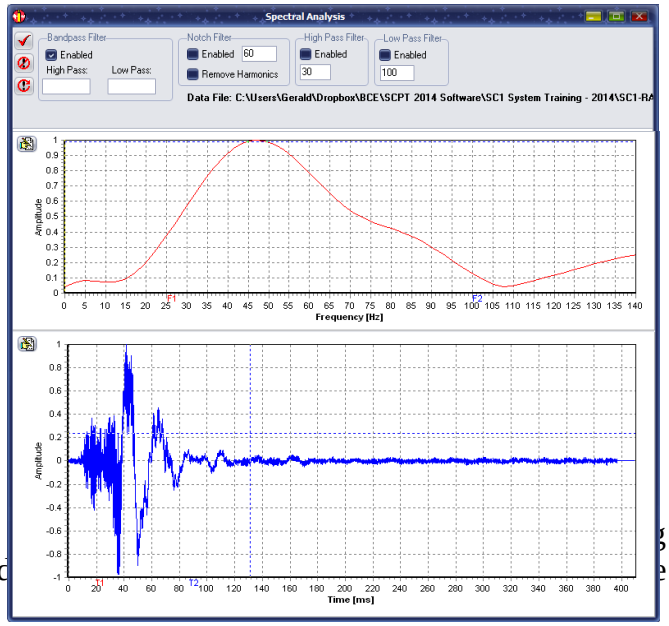



***Figure 15: Data file Dr4.aci seismic data with corresponding frequency spectrum***

The user has the capability to apply a time window on the seismic wave so that the frequency bandpass parameters can be better the cross-hair in the time domain window and button or <Shift> + right or left mouse buttons) which incorporate the desired wave (note : T1 < T2). The user then selects the button so that the specified time window's frequency spectrum is displayed. The selected time window can be cleared by double clicking on the left mouse button.

Figure 15 illustrates the zoomed in frequency spectrum (i.e., 0 to 143 Hz) of the specified time window (ie., T1 and T2). The display includes a panel which allows the user to specify the necessary digital filters to apply to the seismic time series under study. The digital filter implementation is identical to that outlined for the *Cascadable Filter* dialog box. The user can enable a bandpass filter by enabling check box *Bandpass Filter.* The frequency bandpass is selected by pressing the middle mouse button or <shift> + right or left mouse button for each frequency in the bandpass (ie., F1 < F2). Figure 15 illustrates the frequencies selected by the characters F1 and F2. The *Notch, Low Pass* and *High Pass Filters* are enabled by checking the appropriate check boxes and specifying the notch, low pass and high pass frequencies, respectively.

The user repeats this process with the seismic trace defined in data file Ds7.aci. Once the user has interactively defined the digital filter parameters, the filtered traces are displayed as is illustrated in Figure 16. The user may superimpose the filtered onto the unfiltered traces by selecting check box *Unfiltered Traces* as is illustrated in Figure 17.

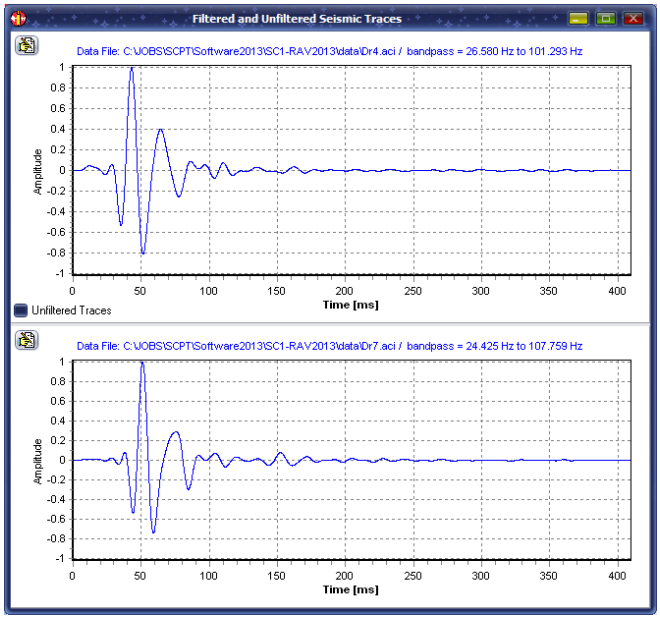

Filtered and Unfiltered Seismic Traces
Data File: C:\JOBS\SCPT\Software2013\SC1-RAV2013\data\Dr4.aci / bandpass = 26.580 Hz to 101.293 Hz
Amplitude
Time [ms]
Unfiltered Traces
Data File: C:\JOBS\SCPT\Software2013\SC1-RAV2013\data\Dr7.aci / bandpass = 24.425 Hz to 107.759 Hz
Amplitude
Time [ms]

***Figure 16: Filtered seismic traces***

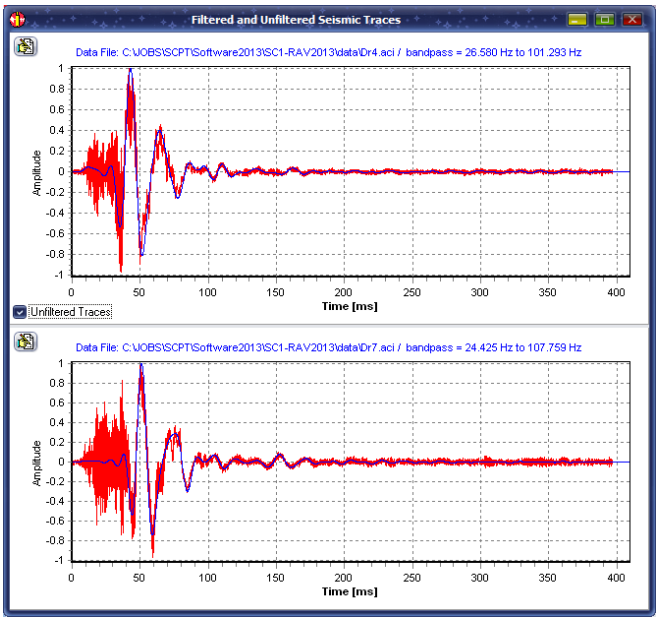

Filtered and Unfiltered Seismic Traces
Data File: C:\JOBS\SCPT\Software2013\SC1-RAV2013\data\Dr4.aci / bandpass = 26.580 Hz to 101.293 Hz
Amplitude
Time [ms]
Unfiltered Traces
Data File: C:\JOBS\SCPT\Software2013\SC1-RAV2013\data\Dr7.aci / bandpass = 24.425 Hz to 107.759 Hz
Amplitude
Time [ms]

***Figure 17: Superposition of filtered traces onto unfiltered seismic traces***

Once the user quits this display, a question box appears (as is shown in Figure 18) and the user is asked whether he wants to re-filter the seismic traces. If the *Yes* push button is selected, then the previously outlined procedure is repeated (i.e., re-specifying the frequency bands). The reason for re-filtering should be apparent from the wave signatures. If the filtered waves appearing in Figure 16 are substantially different, one or both should be re-filtered so as to find waves with similar signatures.

***Figure 18: Question box***

If re-filtering is not required, the two filtered traces will be cross-correlated and the cross-correlation function will be displayed as illustrated in Figure 19. The highest positive value in the cross-correlation function is indicative of the time offset between the seismic traces. Once the user exits the cross-correlation plot, the velocity, depth and accuracy of the interval velocity estimate are then displayed as outlined in Figure 9, and the user is prompted whether he would like to store estimates in a data file as was described in Figures 10 and 11.

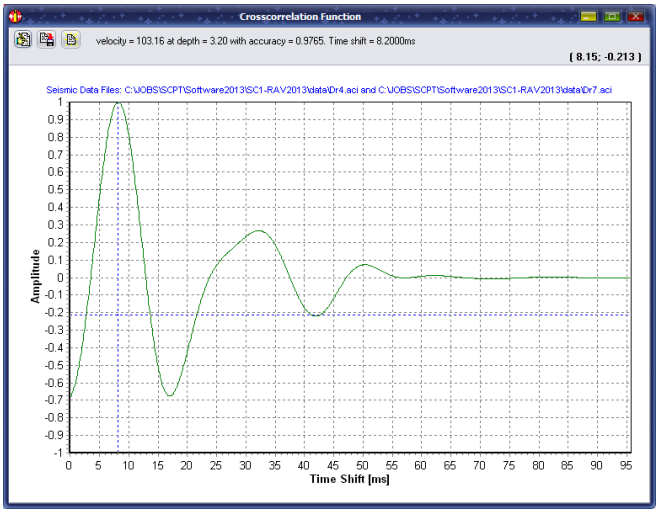

Crosscorrelation Function
velocity = 103.16 at depth = 3.20 with accuracy = 0.9765. Time shift = 8.2000ms
( 8.15; -0.213 )
Seismic Data Files: C:\JOBS\SCPT\Software2013\SC1-RAV2013\data\Dr4.aci and C:\JOBS\SCPT\Software2013\SC1-RAV2013\data\Dr7.aci
Amplitude
Time Shift [ms]

***Figure 19: Cross-correlation function between filtered seismic data defined in files Ds4.aci and Ds7.1aci. Maximum correlation value occurs at a shift of 8.1 ms***

The edit button displayed at the top left hand corner of the previously illustrated graphs allows for chart formatting, printing, and exporting. Figure 20 shows the interface box

that appears when the edit button is selected. This box allows for extensive modification of the displayed data and chart attributes, as well as the print settings. This interface box has an extensive electronic help function that can be accessed by selecting the help button in this box.

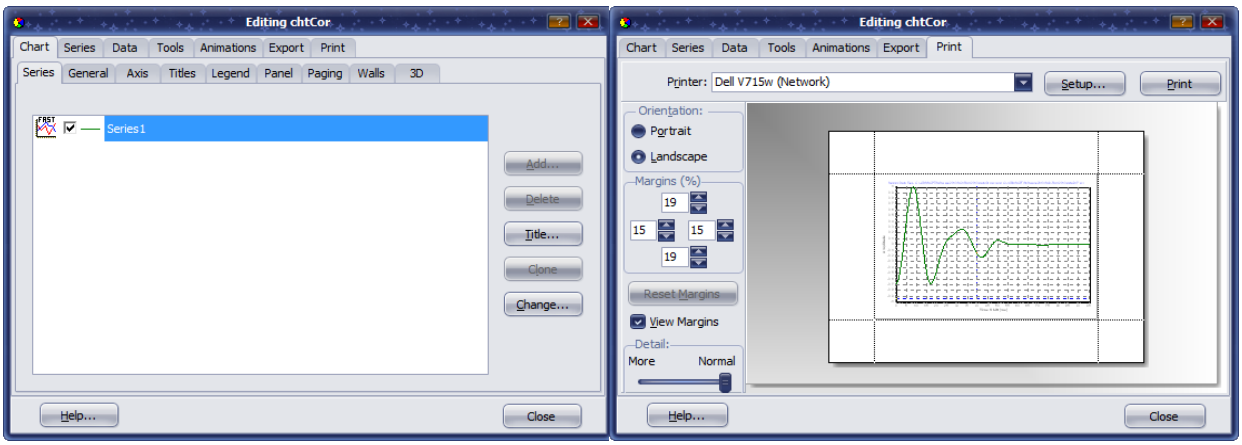



***Figure 20: Chart Editing & Printing dialog box***

The user can also save the modified chart templates by selecting the *Save Chart Settings* button (middle button on the top left corner of the Cross-correlation Function screen). Once this button has been selected, a configuration file containing the template information is stored in subdirectory ..\SC1-RAV\chartCFG. When ***SC1-RAV™*** is reopened, the user may reload the chart template by selecting the *Load Chart Settings* button (right button on the top left corner of the Cross-correlation Function screen). The chart formatting, printing and exporting functionality is provided for all charts displayed within ***SC1-RAV™***.

### *3.1.1.2 Batch Job Analysis*

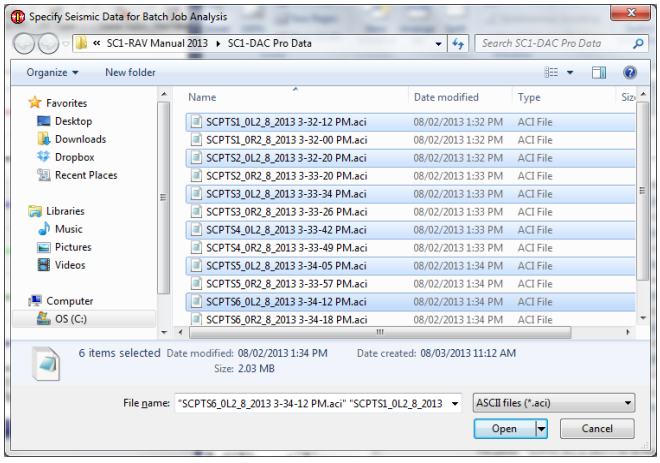

Specify Seismic Data for Batch Job Analysis
SC1-RAV Manual 2013 ▸ SC1-DAC Pro Data
Search SC1-DAC Pro Data
Organize
New folder
Favorites
Desktop
Downloads
Dropbox
Recent Places
Libraries
Music
Pictures
Videos
Computer
OS (C:)
Name
Date modified
Type
SCPTS1_0L2_8_2013 3-32-12 PM.aci 08/02/2013 1:32 PM ACI File
SCPTS1_0R2_8_2013 3-32-00 PM.aci 08/02/2013 1:32 PM ACI File
SCPTS2_0L2_8_2013 3-32-20 PM.aci 08/02/2013 1:32 PM ACI File
SCPTS2_0R2_8_2013 3-33-20 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS3_0L2_8_2013 3-33-34 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS3_0R2_8_2013 3-33-26 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS4_0L2_8_2013 3-33-42 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS4_0R2_8_2013 3-33-49 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS5_0L2_8_2013 3-34-05 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS5_0R2_8_2013 3-33-57 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS6_0L2_8_2013 3-34-12 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS6_0R2_8_2013 3-34-18 PM.aci 08/02/2013 1:34 PM ACI File
6 items selected Date modified: 08/02/2013 1:34 PM Date created: 08/03/2013 11:12 AM
Size: 2.03 MB
File name: "SCPTS6_0L2_8_2013 3-34-12 PM.aci" "SCPTS1_0L2_8_2013
ASCII files (*.aci)
Open
Cancel

***Figure 21: Batch Job Analysis dialog box***

The *Batch Job Analysis* option outlined in Figure 5 facilitates the user to process many seismic traces with similar filter parameters in a batch mode. In addition, *Batch Job Analysis* allows for the estimation of the arrival times for each depth increment and the implementation of Linear Least Squares Regression (LLSR) to derive interval velocities, which minimizes the variability of the interval velocities. The LLSR utilizes three adjacent cross-correlated relative arrival times, the corresponding time series depth and a reference arrival time and depth to determine the slope of the best fitting line through the three points. The slope of the best fitting line is then defined as the interval velocity. In other words, the LLSR applies linear regression on three depth adjacent source waves (e.g., 7m, 8m, and 9m) within a vertical seismic profile (arrival time vs depth plot) so that smoothed interval velocity estimates are obtained.

In the standard application of *Batch Job Analysis* the user selects push button *Begin Processing* in the screen shown in Figure 5. The file input dialog box shown in Figure 21 then appears. The user can input multiple seismic files in this dialog box (i.e., <SHIFT> plus left mouse click or <CTRL> plus left mouse click), but these files should be related (i.e., either all from the right or the left side) and have corresponding incremental depths. The program automatically sorts the traces according to their respective depths. The user then specifies the appropriate filter parameters and selects the *OK* button from the *Cascadable Filters* dialog box shown in Figure 7.

Upon data processing completion, the program displays the average depths, calculated interval velocities together with the corresponding accuracies and relative arrival times as is shown in Figure 22. The user can save these results to file (e.g., for later *Interval Velocity* profiling) by putting check marks next to the values to be saved (all the results can be selected automatically be selecting the red check button ) and selecting the graphical store data push button in panel *Batch Job Results*.

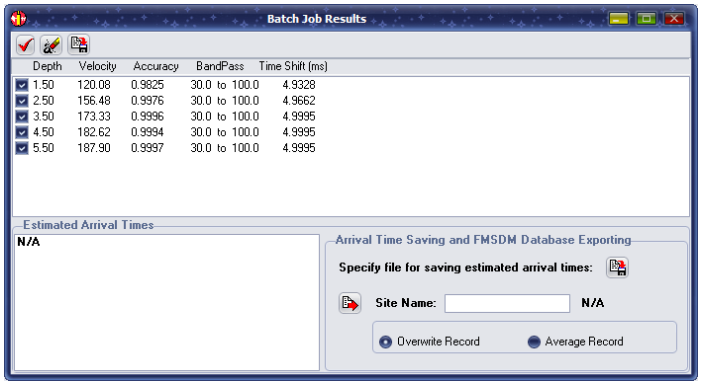

Batch Job Results
Depth Velocity Accuracy BandPass Time Shift (ms)
1.50 120.08 0.9825 30.0 to 100.0 4.9328
2.50 156.48 0.9976 30.0 to 100.0 4.9662
3.50 173.33 0.9996 30.0 to 100.0 4.9995
4.50 182.62 0.9994 30.0 to 100.0 4.9995
5.50 187.90 0.9997 30.0 to 100.0 4.9995
Estimated Arrival Times
N/A
Arrival Time Saving and FMSDM Database Exporting
Specify file for saving estimated arrival times:
Site Name:
N/A
Overwrite Record
Average Record

***Figure 22: Output after implementation of standard Batch Job Analysis***

The user can obtain estimates of the arrival times for each depth increment by enabling check box *Display and Calculate Arrival Times* as outlined in Figure 5. In this case, the user must first specify a reference arrival time and vertical depth (based upon the first break) for one of the seismic time series under analysis.

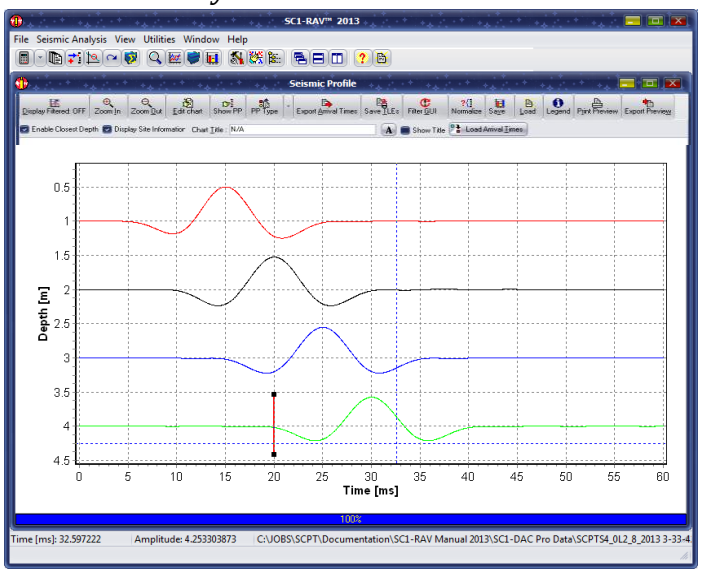



***Figure 23: Estimating a reference arrival time of 20 ms at a vertical depth of 4 m***

The reference arrival time and depth values can easily be obtained by implementing the *View - VSP Display* as outlined in section 4.2. The user then selects a trace as near to the surface as possible where a clear arrival is present. **The reason for selecting a shallow trace is because the main impact of surface refraction occurs near surface.** For example, Figure 23 illustrates a vertical seismic profile with the time series acquired at 4.0 m having an approximate first break arrival time of 20 ms. The subsequent DST arrival times are then derived based upon the calculated cross-correlation relative arrival times and the user specified reference arrival time and corresponding vertical depth. The DST arrival times are important input parameters into the Forward Modeling Downhole Simplex Method (FMDSM) as outlined in Section 3.1.3.

The panel *Arrival Time Saving and Exporting* allow for the user to save estimated arrival times and exporting to the FMDSM database. As illustrated in Figure 24, the *Estimated Arrival Times* can be saved by selecting button .

The ability to export the estimated arrival times to the FMDSM database provides significant post processing time saving. The *SC1-RAV™* software either extracts the *Site Name* from a *SC1-DAC™* file based upon the *SC1-DAC™* automatic file naming convention or, if an alternative acquisition system is utilized. the investigator is required to manually input the desired *Site Name* within the text box provided (the default entry for this field is "SCPT"). By clicking on button the estimated arrival times are exported to the FMDSM database

When exporting the data the user can select from two options. When option *Overwrite Record* is selected (which is also the default setting) data previously stored in the database are overwritten and the new data are stored in the FMDSM database with measurement weights set to 1. However, in a typical SH-wave FMDSM analysis procedure the first arrival time estimates exported are estimates obtained from "right side" (seismic traces acquired from the "right side" of the seismic probe). Next the estimated "left side" arrival times should be exported to the FMDSM database. By selecting the option *Average Record* selected the estimated arrival times from the "right side" (already in the database) and "left side" will be averaged and stored in the FMDSM database with measurement weights set to 1.

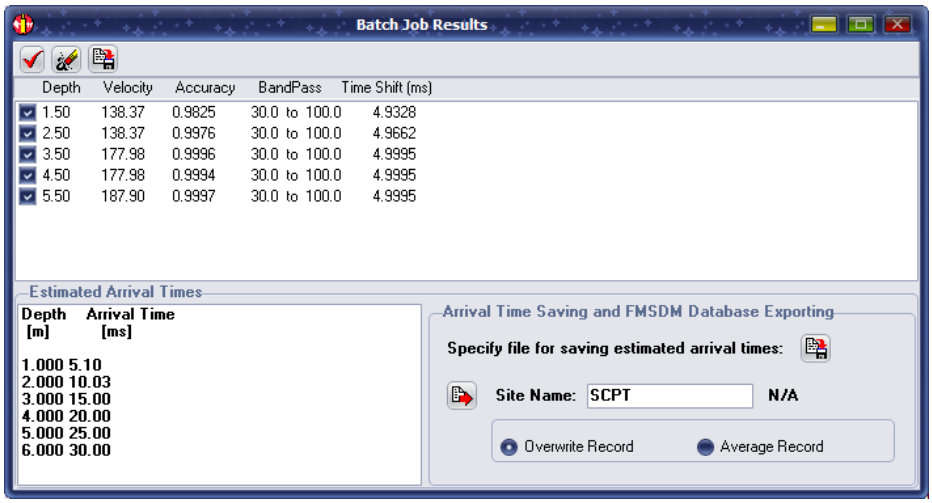

Batch Job Results
Depth Velocity Accuracy BandPass Time Shift (ms)
1.50 138.37 0.9825 30.0 to 100.0 4.9328
2.50 138.37 0.9976 30.0 to 100.0 4.9662
3.50 177.98 0.9996 30.0 to 100.0 4.9995
4.50 177.98 0.9994 30.0 to 100.0 4.9995
5.50 187.90 0.9997 30.0 to 100.0 4.9995
Estimated Arrival Times
Depth [m] Arrival Time [ms]
1.000 5.10
2.000 10.03
3.000 15.00
4.000 20.00
5.000 25.00
6.000 30.00
Arrival Time Saving and FMSDM Database Exporting
Specify file for saving estimated arrival times:
Site Name: SCPT
N/A
Overwrite Record
Average Record

***Figure 24: Implementation of the LLSR technique on the relative arrival times illustrated in Figure 20***

### 3.1.2 Reverse Polarity Technique

The *Reverse Polarity Technique* dialog box is illustrated in Figure 25. In this option the user specifies four seismic data files to be processed outlined as follows:

1. *Polarized Files at Depth1* - The user selects two files which correspond to reversely polarized waves acquired at the same depth - Depth1.
2. *Polarized Files at Depth2* - The user selects two files which correspond to reversely polarized *waves acquired at the same depth - Depth2.

Reverse Polarity Technique
Polarized Files at Depth1
C:\JOBS\SCPT\Documentation\SC1-RAV Manual 2013\SC1-DAC Pro Data\SCPTS2_0L2_8_2013 3-32-20 PM.aci + C:\JOBS\SCPT\Documentation\SC
Polarized Files at Depth2
C:\JOBS\SCPT\Documentation\SC1-RAV Manual 2013\SC1-DAC Pro Data\SCPTS3_0L2_8_2013 3-33-34 PM.aci + C:\JOBS\SCPT\Documentation\SC
OK
Cancel

***Figure 25: Reverse Polarity Technique dialog box***

It is required that Depth2 is greater than Depth1. The user can make the required selections by pressing the left mouse button together with the <CTRL> or <Shift> key.

Once the above data files have been specified, the user then selects the *OK* push button, after which the program will ask the user to specify, if applicable, the filtering parameters for the data files selected. Once the traces are filtered, if necessary, the seismic traces are displayed as is illustrated in Figure 26.

The user is required to select interactively (i.e., with the mouse) the crossover point at depth1 (i.e., T1) and the crossover point at depth2 (i.e., T2). The crosshair is moved to the desired crossover point and the middle mouse button or <Shift>+right or left mouse button is selected. The crossover point selection can be cleared by double clicking the left mouse button.

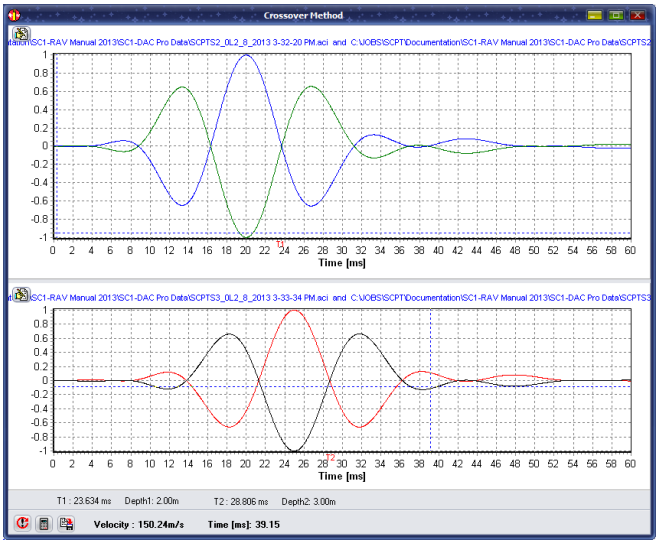



***Figure 26: Graphical output from the Reverse Polarity Technique***

The user selects the *Calculator* icon to determine the velocity (with travel path corrections) corresponding to the crossover times selected. The calculated velocity is displayed at the bottom of the chart as is illustrated in Figure 26. The user may then save this information in a velocity file (by selecting ) as previously described. This allows for easier interval velocity comparisons between *Reverse Polarity* and *Cross-correlation* techniques.

### 3.1.3 Forward Modeling Downhill Simplex Method

The Forward Modeling / Downhill Simplex Method (FMDSM) utilizes seismic ray tracing and optimal estimation techniques to derive DST interval velocities. The standard techniques implemented to determine DST interval velocities rely upon obtaining reference P and S wave arrival times as the probe is advanced into the soil profile. By assuming a straight ray travel path from source to seismic receiver and calculating relative reference arrival time differences, interval DST velocities are obtained.

The FMDSM offers distinct advantages over conventional DST velocity profile estimation methods, such as:

- utilization of Snell's Law at layer boundaries for ray path refraction.
- optimization of a non-linear cost function, which takes into account more details of the DST testing environment and the recorded seismic data.
- allowance for measurement weights to be specified, the possibility to incorporate unlimited input data (e.g., crossover point arrival times, maximum cross-correlation time shifts, angles of incidence and P-wave / S-wave time separations) into the interval velocity estimation algorithm.
- ability to accurately interpolate interval velocities when measurement data are not available.
- reporting of meaningful error residuals, which indicate the accuracy of the estimated interval velocity.

Please refer to Appendix 2 for further details nd the ability of the FMSDM to obtain variable interval velocity estimates. In the *FMDSM* the user is provided with a user friendly interface to specify seismic wave arrival times with corresponding weights within a Windows® compatible database. This information is derived from implementing ***SC1-RAV™*** menu options *Cross-correlation Technique->Batch Job Analysis* with *Display and Calculate Arrival Times* option enabled. The graphical screen illustrated in Figure 27 appears when the *FMDSM* menu option is selected.

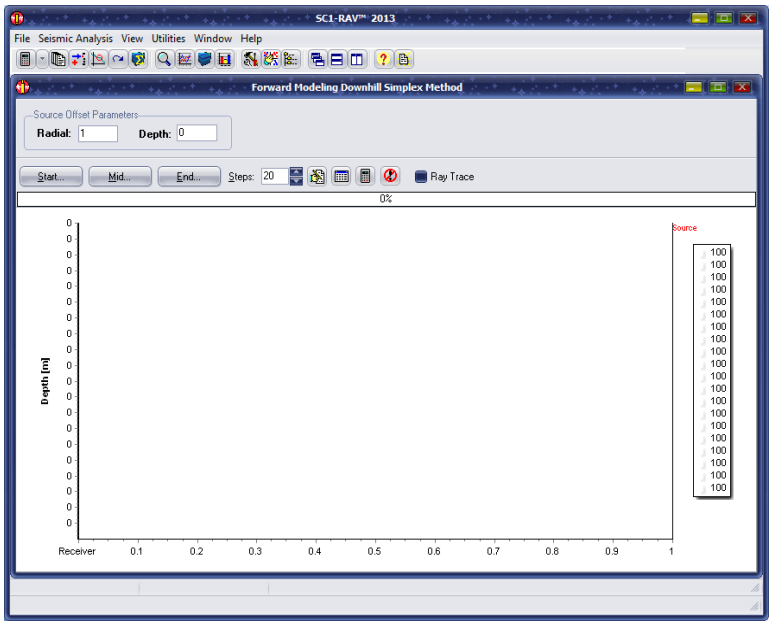



***Figure 27: Main graphical interface screen in the FMDSM software option showing the Source Offset Parameters input tab***

The first step in implementing the FMDSM is for the user to specify important parameters:

*Radial*: The radial offset of the DST source from the seismic receiver.
*Depth*: The depth offset of the DST source from the ground surface.

Once these parameters have been specified, the user must either generate or select a database which contains the required DST arrival times. This step is carried out selecting the *Database* icon , after which the graphical database interface illustrated in Figure 28 appears.

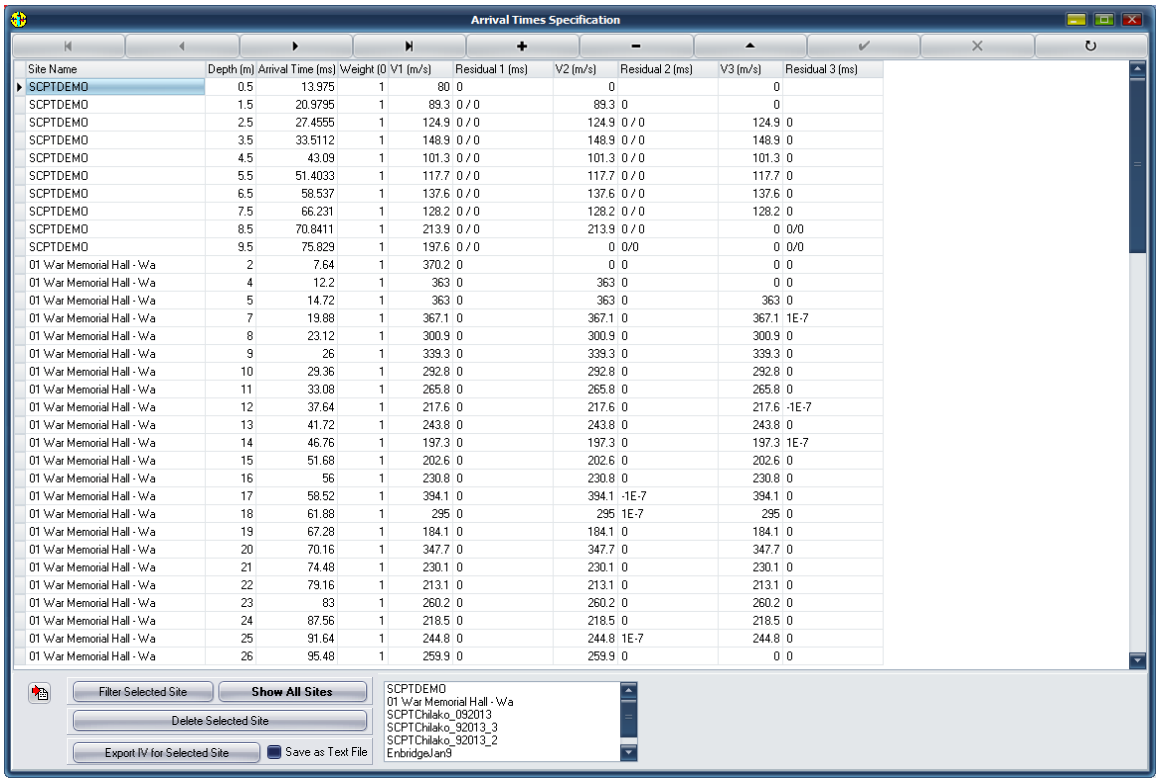



***Figure 28: FMDSM database interface illustrating inputted data for all available sites***

As shown in Figure 28 at the top of the interface there are ten buttons with which the user manipulates the database:

| | | | |
|---|---|---|---|
| ⏮ | move to the beginning of the list | - | delete record |
| ◀ | move one record back | ▲ | edit a record |
| ▶ | move one record forward | ✓ | post record |
| ⏭ | move to the end of the list | X | undo edit |
| + | insert record | ↻ | update list |

In addition, there are one icon, 4 buttons and one checkbox at the bottom of the interface:

***Figure 29: Database control buttons***

- the *Process Selected Site Data* icon initiates the FMDSM analysis
- the *Filter Selected Site* button allows the user to filter the arrival time information for a specific site by highlighting that site within the scroll list of available sites (on bottom of the user interface window). The filtered arrival time information for site SCPTDemo is illustrated in Figure 30.
- the *Show All Sites* button allows the user to undo previous data filtering.
- the *Delete Selected Site* button allow the user to delete a specific site by highlighting that site within the scroll list of available sites (on bottom of the user interface window).
- The *Export IV for Selected Site* button allows the user to export the estimated FMDSM interval velocities (IV) for a specific site by highlighting that site within the scroll list of available sites (on bottom of the user interface window). When button is clicked a dialog box to enter specific test information appears as was outlined in Figure 10. Alternatively, if checkbox *Save as Text File* is checked then the FMDSM interval velocities are saved in a simplified format, so the output can be easily incorporated into a Word® table or Excel® spreadsheet.

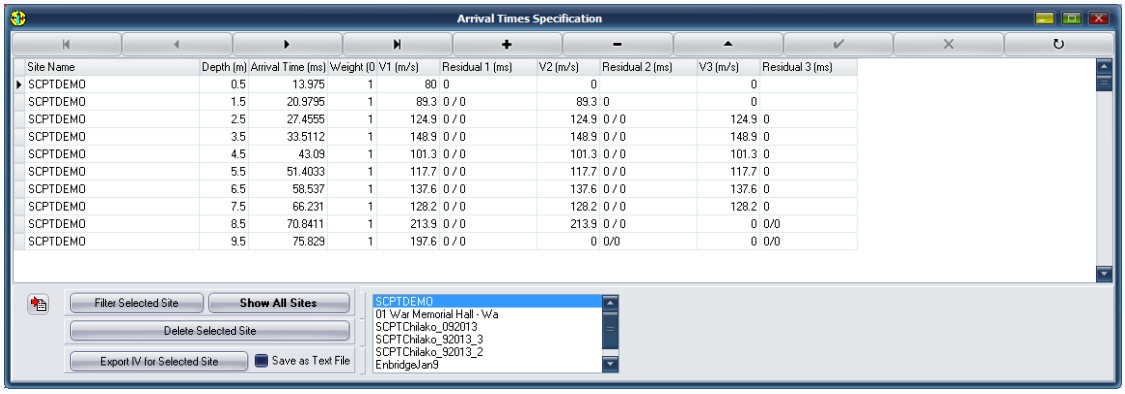

Arrival Times Specification
Site Name | Depth (m) | Arrival Time (ms) | Weight (0 | V1 (m/s) | Residual 1 (ms) | V2 (m/s) | Residual 2 (ms) | V3 (m/s) | Residual 3 (ms)
SCPTDEMO | 0.5 | 13.975 | 1 | 80 | 0 | 0 | | 0 |
SCPTDEMO | 1.5 | 20.9795 | 1 | 89.3 | 0 / 0 | 89.3 | 0 | 0 |
SCPTDEMO | 2.5 | 27.4555 | 1 | 124.9 | 0 / 0 | 124.9 | 0 / 0 | 124.9 | 0
SCPTDEMO | 3.5 | 33.5112 | 1 | 148.9 | 0 / 0 | 148.9 | 0 / 0 | 148.9 | 0
SCPTDEMO | 4.5 | 43.09 | 1 | 101.3 | 0 / 0 | 101.3 | 0 / 0 | 101.3 | 0
SCPTDEMO | 5.5 | 51.4033 | 1 | 117.7 | 0 / 0 | 117.7 | 0 / 0 | 117.7 | 0
SCPTDEMO | 6.5 | 58.537 | 1 | 137.6 | 0 / 0 | 137.6 | 0 / 0 | 137.6 | 0
SCPTDEMO | 7.5 | 66.231 | 1 | 128.2 | 0 / 0 | 128.2 | 0 / 0 | 128.2 | 0
SCPTDEMO | 8.5 | 70.8411 | 1 | 213.9 | 0 / 0 | 213.9 | 0 / 0 | 0 | 0/0
SCPTDEMO | 9.5 | 75.829 | 1 | 197.6 | 0 / 0 | 0 | 0/0 | 0 | 0/0
Filter Selected Site
Show All Sites
Delete Selected Site
Export IV for Selected Site
Save as Text File
SCPTDEMO
01 War Memorial Hall - Wa
SCPTChilako_092013
SCPTChilako_92013_3
SCPTChilako_92013_2
EnbridgeJan9

***Figure 30: Filtering DST site SCPTDEMO***

In a typical FMDSM analysis, the user will firstly obtain a DST profile of the cross-correlation time shifts using the *Cross-correlation Technique* as previously outlined. Next the user reviews all the recorded seismic cone time series data within a Vertical Seismic Profile (VSP) by implementing the *View – VSP Display* menu option (see Section 4.2). The best P-wave or S-wave arrival time from the VSP is selected and arrival times are then derived for each depth increment utilizing this reference arrival time and the previously derived cross-correlation shifts. As mentioned previously, the *Batch Processing* software option automates the task of obtaining VSP arrival times.

For example (using the SCPTDEMO data in Figure 28), if the best arrival time occurred at 3.5 m and is estimated to be 33.5 ms, then the arrival time at 2.5 m would be 27.4 ms for a time shift of 6.1 ms (33.5 ms - 6.1 ms), the arrival time at 1.5 m would be 20.9 ms for a time shift of 6.5 ms (27.4 ms - 6.5 ms), and the arrival time at 4.5 m would be 43.1 ms for a time shift of 9.6 (33.5 ms + 9.6 ms). This process is carried out for the complete DST profile and then the corresponding *Arrival Times* are inputted with measurement weights set to reflect the corresponding cross-correlation coefficient or typically set to 1.0. If the recorded seismic waves have poor correlation to one another, then the user can simply input arrival times based upon best estimates.

The FMDSM database interface is a standard windows database where the user can filter specific sites and add in new sites with arrival time information. For example, Figure 28 shows the FMDSM database for sites SCPT2013, SCPTDEMO, SCPT2, SCPTRightSide, SCPT3RightSide, SCPT3LeftSide, and SCPT4RightSide.

A new database is specified in one of three ways:

1. Automatically as previously described in *Seismic Analysis-Interval Velocities- Cross-correlation Technique-Batch Processing* (see Section 3.1.1.2).
2. Manually by going to the bottom of the main FMDSM database list, moving the cursor down one row and typing in a new site name. After that move the cursor to the Depth (m) column and type in the corresponding depth, move the cursor to the Arrival Time (ms) column and type in appropriate arrival time, and finally move the cursor to the Weight column and type in the appropriate measurement weight (usually 1.0). Figure 31 shows an example of the previously implemented steps for test site SCPTNew.

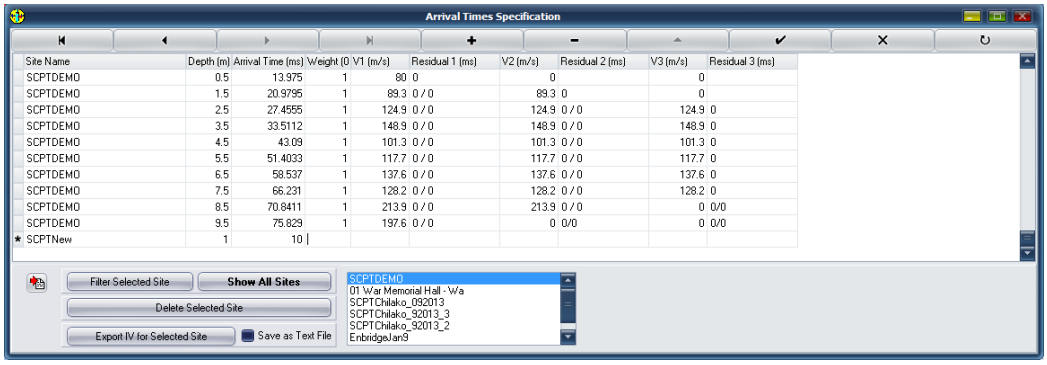

Arrival Times Specification
Site Name | Depth (m) | Arrival Time (ms) | Weight (0 | V1 (m/s) | Residual 1 (ms) | V2 (m/s) | Residual 2 (ms) | V3 (m/s) | Residual 3 (ms)
SCPTDEMO 0.5 13.975 1 80 0 0 0
SCPTDEMO 1.5 20.9795 1 89.3 0 / 0 89.3 0 0
SCPTDEMO 2.5 27.4555 1 124.9 0 / 0 124.9 0 / 0 124.9 0
SCPTDEMO 3.5 33.5112 1 148.9 0 / 0 148.9 0 / 0 148.9 0
SCPTDEMO 4.5 43.09 1 101.3 0 / 0 101.3 0 / 0 101.3 0
SCPTDEMO 5.5 51.4033 1 117.7 0 / 0 117.7 0 / 0 117.7 0
SCPTDEMO 6.5 58.537 1 137.6 0 / 0 137.6 0 / 0 137.6 0
SCPTDEMO 7.5 66.231 1 128.2 0 / 0 128.2 0 / 0 128.2 0
SCPTDEMO 8.5 70.8411 1 213.9 0 / 0 213.9 0 / 0 0 0/0
SCPTDEMO 9.5 75.829 1 197.6 0 / 0 0 0/0 0 0/0
SCPTNew 1 10
Filter Selected Site
Show All Sites
Delete Selected Site
Export IV for Selected Site
Save as Text File
SCPTDEMO
01 War Memorial Hall - Wa
SCPTChilako_092013
SCPTChilako_92013_3
SCPTChilako_92013_2
EnbridgeJan9

***Figure 31: Specifying a new DST FMDSM database***

Next select the *Show All sites* or *Refresh data* ↻button and subsequently filter the newly created site (e.g., SCPTNew) by highlighting it within the scroll list of available sites (on bottom of the user interface window), and selecting the *Filter Selected Site* button. Complete population of the new site by inputting all available depths and corresponding arrival times and weights as illustrated in Figure 32.

3. Manually by selecting the database interface + instead of moving to the bottom of the list. After that the steps described under option 2 are performed.

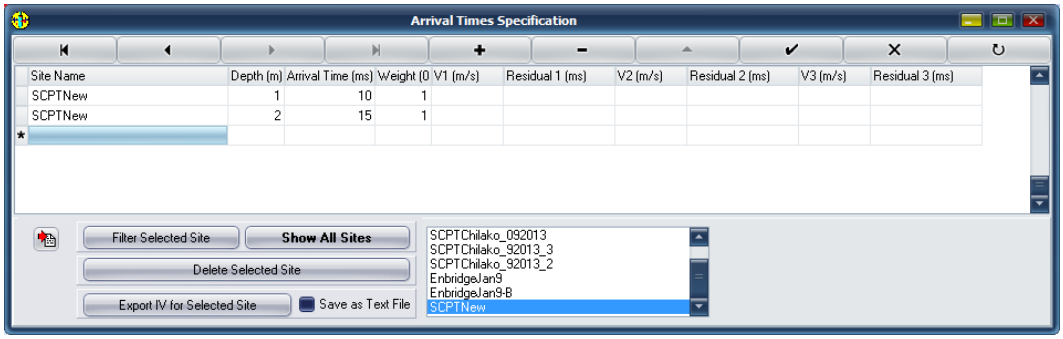



***Figure 32: Filtering a newly created database (SCPTNew) with theinitial entries illustrated***

After selecting the desired DST site, the user then clicks icon to commence the implementation of the FMDSM This will return the program to the *FMDSM* main graphical screen previously illustrated in Figure 27, where icon has to be selected to execute the FMDSM algorithm . The user may abort the *FMDSM* by selecting icon .

Upon completion of the *FMDSM*, the screen shown in Figure 33[2] appears: a graphical representation of the estimated interval velocities with ray tracing implemented by checking box *Ray Trace*. The color gradient of the graphic can be changed by selecting push buttons *Start...*, *Mid...*, and *End...* Dial *Steps* allow the user to modify the color step increments in the interval velocity display. The estimated interval velocities are entered into the selected database as shown in Figure 34.

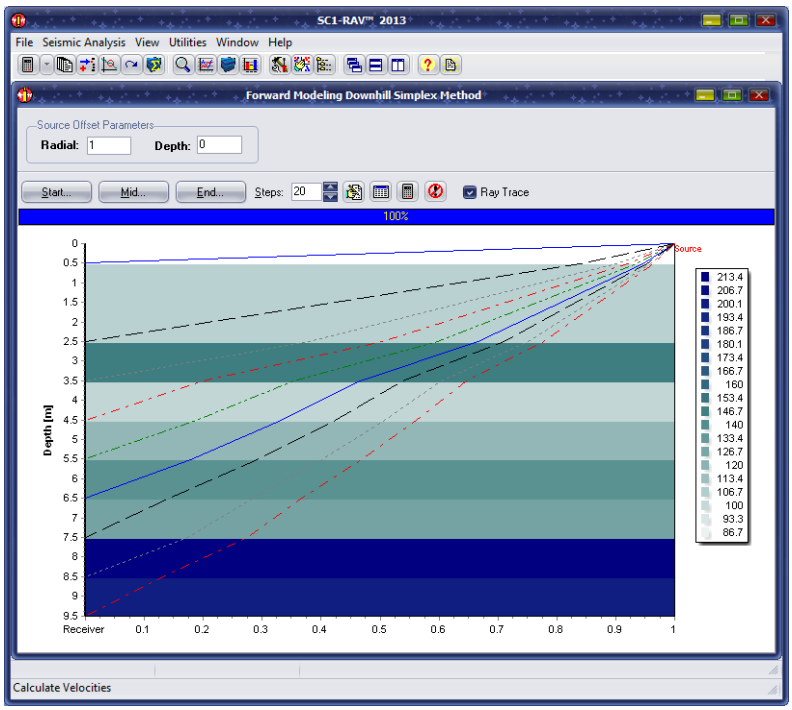



***Figure 33: FMDSM graphical screen after completion of the interval velocity***

[2] The results shown in Figure 33 are derived with the SCPTDEMO database provided within the ***SC1-RAV™*** software installation package. In this SCPTDEMO database there are measurements for depths from 0.5 m to 9.5 m with a depth increment of 1. In this example, the *Source Depth Offset* is set to 0 and the *Source Radial Offset* is 1.0 m

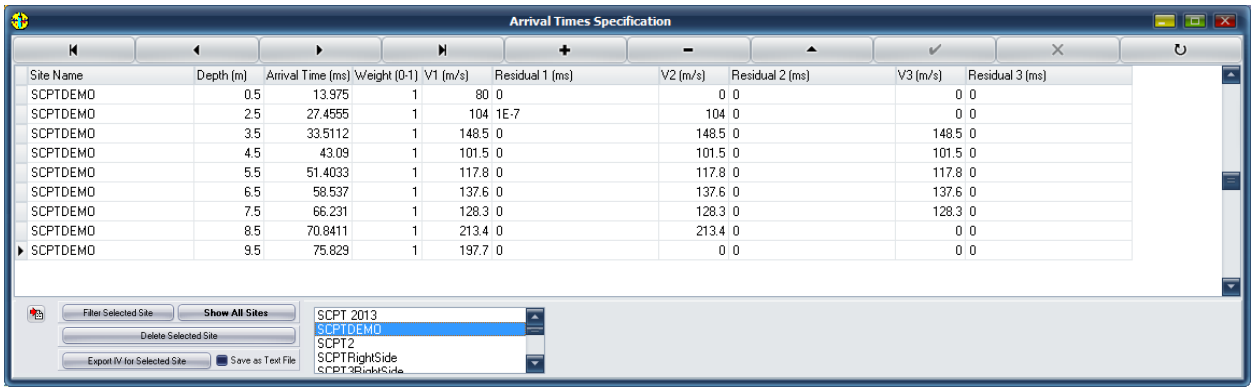

Arrival Times Specification
Site Name | Depth (m) | Arrival Time (ms) | Weight (0-1) | V1 (m/s) | Residual 1 (ms) | V2 (m/s) | Residual 2 (ms) | V3 (m/s) | Residual 3 (ms)
SCPTDEMO | 0.5 | 13.975 | 1 | 80 | 0 | 0 | 0 | 0 | 0
SCPTDEMO | 2.5 | 27.4555 | 1 | 104 | 1E-7 | 104 | 0 | 0 | 0
SCPTDEMO | 3.5 | 33.5112 | 1 | 148.5 | 0 | 148.5 | 0 | 148.5 | 0
SCPTDEMO | 4.5 | 43.09 | 1 | 101.5 | 0 | 101.5 | 0 | 101.5 | 0
SCPTDEMO | 5.5 | 51.4033 | 1 | 117.8 | 0 | 117.8 | 0 | 117.8 | 0
SCPTDEMO | 6.5 | 58.537 | 1 | 137.6 | 0 | 137.6 | 0 | 137.6 | 0
SCPTDEMO | 7.5 | 66.231 | 1 | 128.3 | 0 | 128.3 | 0 | 128.3 | 0
SCPTDEMO | 8.5 | 70.8411 | 1 | 213.4 | 0 | 213.4 | 0 | 0 | 0
SCPTDEMO | 9.5 | 75.829 | 1 | 197.7 | 0 | 0 | 0 | 0 | 0
Filter Selected Site
Show All Sites
Delete Selected Site
Export IV for Selected Site
Save as Text File
SCPT 2013
SCPTDEMO
SCPT2
SCPTRightSide

***Figure 34: Automatic insertion of the estimated interval velocities and corresponding error residuals into the FMDSM database***

The FMDSM is capable of estimating up to three interval velocities. These values are represented by columns *V1 (m/s)*, V2 (m/s), and *V3 (m/s)*. Due to the structure of the FMDSM, there is only one interval velocity for the first and last layers and two interval velocities for the second and second to last layers. Interval velocities defined as 0 imply that no estimate was available.

The columns *Residual 1 (ms)*, *Residual 2 (ms)* and *Residual 3 (ms)* identify the error residual between the specified *Arrival Times* and synthesized values (Forward Modeling) by implementing the estimated interval velocities. They give an indication of how well our estimated interval velocity model fits the measured data.

The user should place high weight on an FMDSM interval velocity profile when the three velocity columns (*V1 (m/s)*, *V2 (m/s)*, and *V3 (m/s)*) at each depth increment are nearly identical and there are correspondingly low error residuals (which implies a stable solution). **Significant variability in V1 (m/s), V2 (m/s), and V3 (m/s) and/or high error residuals mostly likely are associated with improperly specified arrival times or is indicative of lateral soil heterogeneity**.

## 3.2 Data Stack

The *Data Stack* option allows the user to post-stack acquired seismic cone time series. When selecting this option the file input dialog box shown in Figure 35 appears where the user can select the seismic files to stack. The user can input multiply seismic files in this dialog box (i.e., <SHIFT> plus left mouse click or <CTRL> plus left mouse click).

After specifying the files to be stacked, the user is asked to specify the format of the stacked data file (either ASCII or Binary format, as shown in Figure 36) and the directory and name for this file (as is shown in Figure 37).

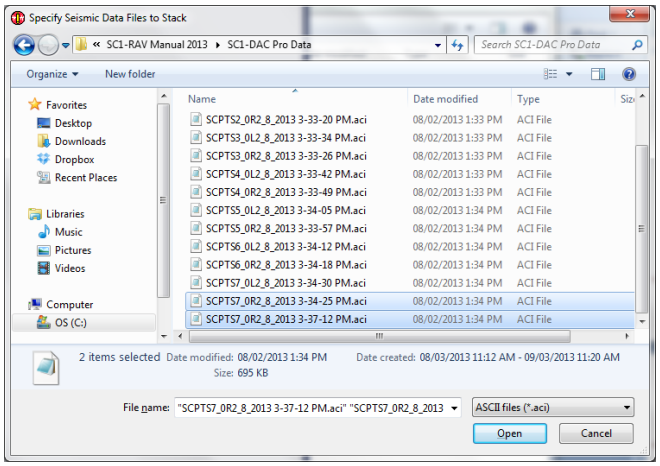

Specify Seismic Data Files to Stack
SC1-RAV Manual 2013 ▸ SC1-DAC Pro Data
Search SC1-DAC Pro Data
Organize
New folder
Favorites
Desktop
Downloads
Dropbox
Recent Places
Libraries
Music
Pictures
Videos
Computer
OS (C:)
Name
Date modified
Type
SCPTS2_0R2_8_2013 3-33-20 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS3_0L2_8_2013 3-33-34 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS3_0R2_8_2013 3-33-26 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS4_0L2_8_2013 3-33-42 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS4_0R2_8_2013 3-33-49 PM.aci 08/02/2013 1:33 PM ACI File
SCPTS5_0L2_8_2013 3-34-05 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS5_0R2_8_2013 3-33-57 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS6_0L2_8_2013 3-34-12 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS6_0R2_8_2013 3-34-18 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS7_0L2_8_2013 3-34-30 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS7_0R2_8_2013 3-34-25 PM.aci 08/02/2013 1:34 PM ACI File
SCPTS7_0R2_8_2013 3-37-12 PM.aci 08/02/2013 1:34 PM ACI File
2 items selected Date modified: 08/02/2013 1:34 PM Date created: 08/03/2013 11:12 AM - 09/03/2013 11:20 AM
Size: 695 KB
File name: "SCPTS7_0R2_8_2013 3-37-12 PM.aci" "SCPTS7_0R2_8_2013
ASCII files (*.aci)
Open
Cancel

***Figure 35: Data Stack file input dialog box***

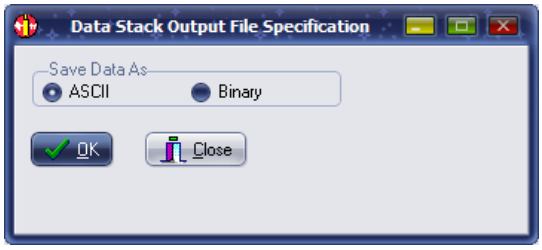



***Figure 36: Specifying the format to save stacked time series***

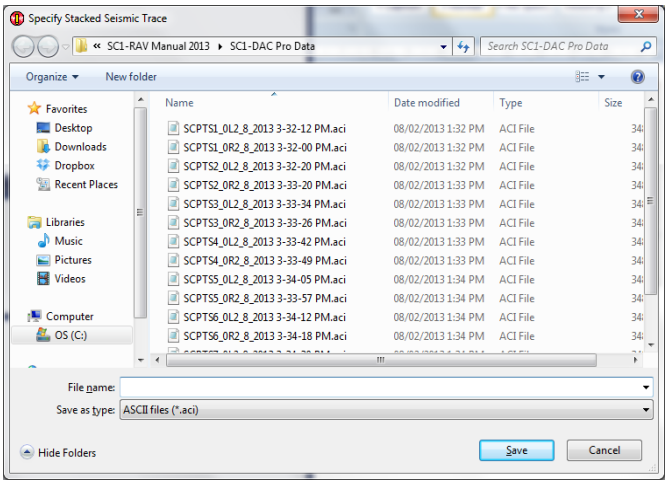



***Figure 37: Specifying the directory and file name of the stacked time series***

## *3.3 Data Interpolation*

This analysis feature allows the user to increase the resolution of the captured seismic data for post processing purposes, which can be useful to obtain relative time shifts utilizing the cross-correlation function, to perform reverse polarity analysis or to specify trend lines in depth profiling. In addition, ***SC1-RAV™****'s Data Interpolation* software feature allows the user to synchronize seismic time series data captured with differing sampling rates (i.e., set data to same sampling rate). Figure 38 illustrates the user interface for *Data Interpolation* with the two options: *Inline Time Series Interpolation* and *Save to File*.

### 3.3.1 Inline Time Series Interpolation

The *Inline Time Series Interpolation* option of *Data Interpolation* linearly interpolates points within the seismic time series with the specified resolution. For example, if the seismic time series data had a sampling rate interval of 0.3 ms (sampling rate of 3.3 KHz), increasing the resolution by 1 unit would decrease the sampling interval rate to 0.15 ms (sampling rate of 6.6 KHz). This option can be implemented as part of the Cross-correlation Technique (see paragraph 3.1.1) and if enabled the data sampling rate of the selected files is increased by the amount specified within the *Resolution* text box (by up to 20 units).

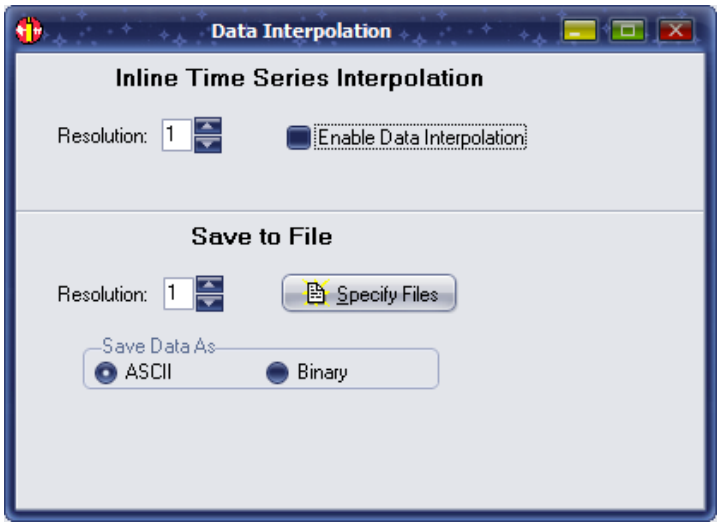



***Figure 38: User interface for Data Interpolation***

### 3.3.2 Save to File

The *Save to File* option of Data Interpolation allows the user to select a set of files, for which the data resolution is increased by the specified Resolution amount. The selected data files are subsequently saved in identically named files with the subscript "_Interp" appended to the name (e.g., DS4.aci becomes DS4_Interp.aci). In addition, the user can specify the format of the new file (either ASCII or Binary format).

## 3.4 Signal Decay

The *Signal Decay* option allows the user to minimize the effect of possible source wave multiples on the first arriving source wave, and applies an exponential decay function to the selected time series data after a user specified time. This option can either be applied on an individual trace or in batch mode on a series of traces (see Figure 39).

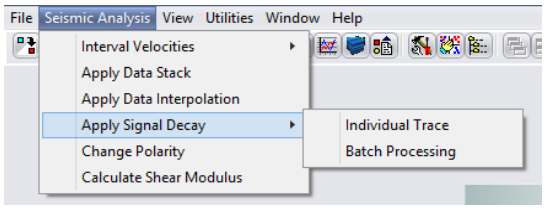



***Figure 39: Apply Signal Decay submenu with corresponding analysis options***

### 3.4.1 Individual Trace

Figure 40 shows the user interface for this software option. The *Initial Time Decay* (ms) and *Decay Factor* (1/ms) are required user input. The *Decay Factor* is defaulted to 1.0. As the *Decay Factor* is increased, there is a sharper decay of the time series data at the specified time index.

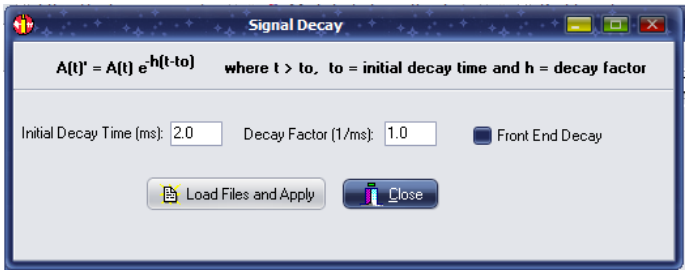

Signal Decay
A(t)' = A(t) e-h(t-to)
where t > to, to = initial decay time and h = decay factor
Initial Decay Time (ms): 2.0
Decay Factor (1/ms): 1.0
Front End Decay
Load Files and Apply
Close

***Figure 40: User interface for Signal Decay (individual trace)***

Figure 41 illustrates the use of this option on time series data with the *Initial Time Delay* set to 154 ms and a *Decay Factor* of 1.0. The traces in red are the decayed seismic data where the effects of the source wave multiples have been minimized significantly. It should be noted that if the user wants to apply the decay from the start of the trace to the Initial Decay Time then check box *Front End Decay* must be checked.

The *Initial Time Decay* parameter assumes that any pre-trigger data has been removed from the seismic trace. For this reason, it is advised that software option *Display Pre-trigger* is unchecked when determining the *Initial Decay Parameter* within software options *View-> VSP Display* and *View->Seismic Data*.

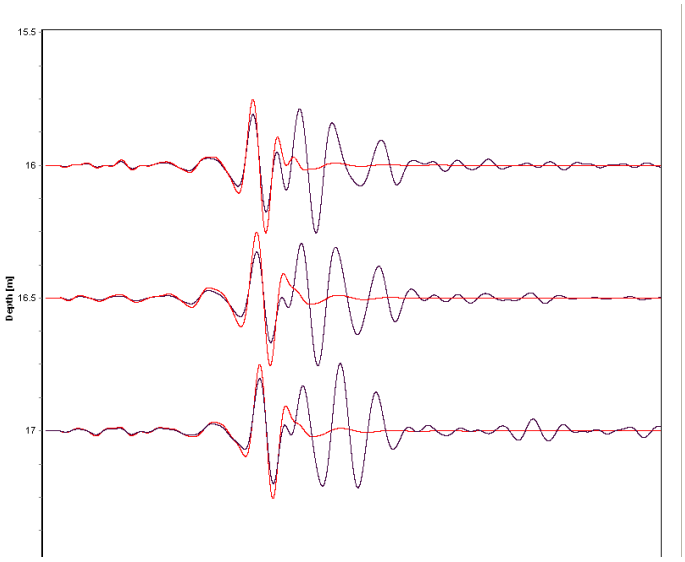



***Figure 41: Example of applying the Signal Decay option to time series data with source wave multiples***

It should be noted that when applying *Signal Decay*, the saved file will not retain the pre-trigger information.

### 3.4.2 Batch Option

Signal decay can also be performed in batch mode, in which case signal decay is applied to the entire trace (i.e. both front and back decay). The algorithm then applies a signal decay time window centered at the time location, *t**, of the absolute maximum amplitude of the seismic trace under analysis. The signal decay time window is defined as the front-end second zero crossing (i.e., moving back in time from *t** until the second zero crossing reached) and back-end second zero crossing from *t**.

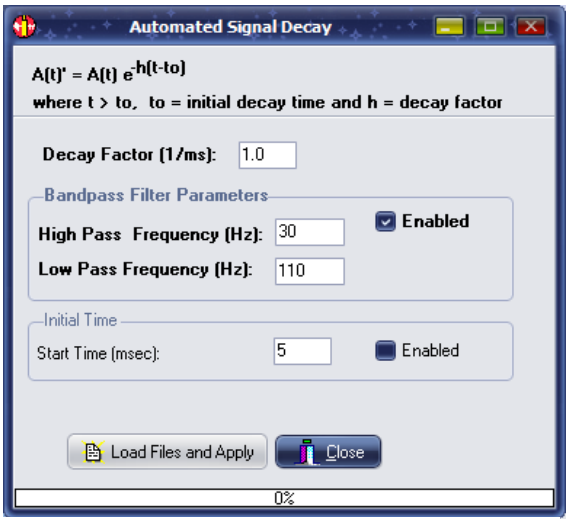



***Figure 42: User interface for Signal Decay (batch processing)***

Figure 42 shows the user interface for this software option. The *Initial Time Decay* (ms) and *Decay Factor* (1/ms) are required user input. The *Decay Factor* is defaulted to 1.0. As the *Decay Factor* is increased, there is a sharper decay of the time series data at the specified time index. The user interface also allows the implementation of a *Bandpass Filter*, and the *Initial Time* parameter is as described in Section 3.1.1.1.1. Next the user presses button *Load Files and Apply* to select the files that need to be processed. Once signal decay has been applied to the selected files the processed files are stored in sub-directory …\ Signal Decay (created in the same directory as the selected files, if not already present) and renamed with '_SD' appended to the file name.

Figures 43, 44 and 45 illustrate the use of the *Initial Time* parameter. Figure 43 oultines a VSP where there is a strong seismic response (within 20 ms) prior to the arrival of the desired SH wave (starting at approximately 60 ms at depth 12m. Figure 44 shows the same VSP after applying an *Intitial Time* of 60 ms, while Figure 45 shows the outcome when applying batch decay with this *Initial Time*. From the figure it is clear that the source wave has been isolated.

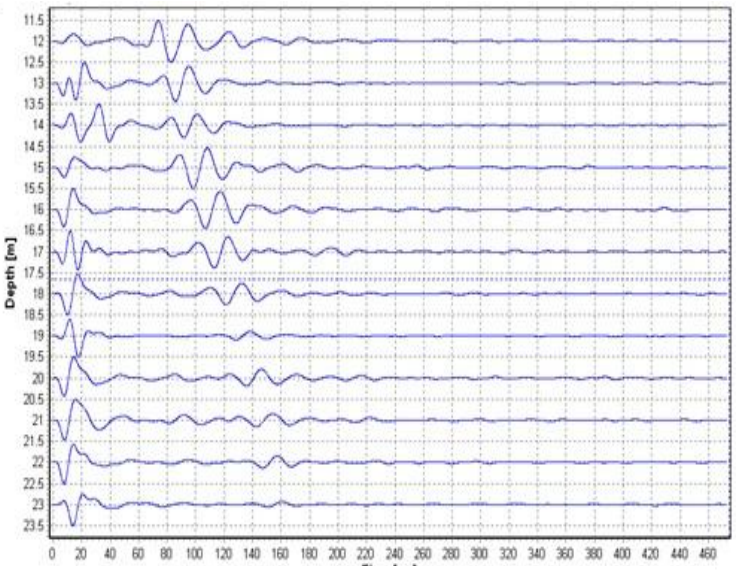



***Figure 43: VSP with a strong seismic response prior to the arrival of the SH wave***

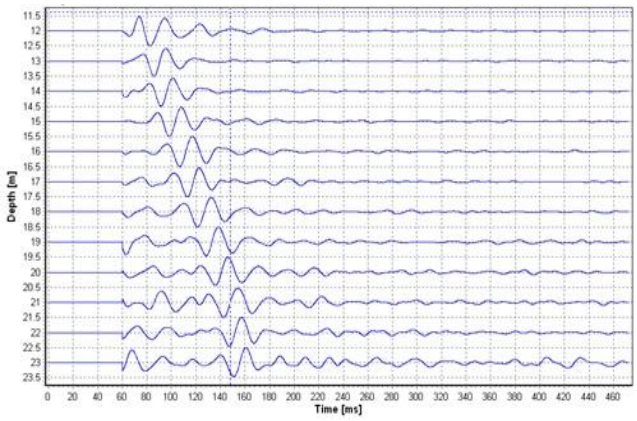



***Figure 45: VSP in Figure 42 after application of an Initial Time of 60 ms***

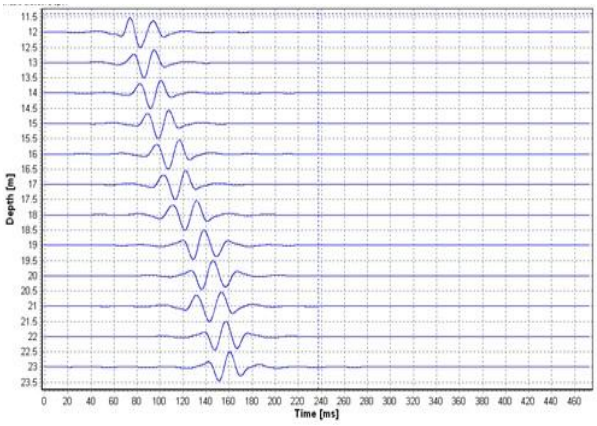



***Figure 44: VSP illustrated in Figure 43 after application of signal decay***

## 3.5 Change Polarity

The *Change Polarity* option facilitates the user in selecting a set of seismic data files and subsequently changing the polarity of the time series.

## 3.6 Calculate Shear Modulus

The *Shear Modulus Calculation* option allows the user to specify (and then read in) an interval shear wave velocity ($V_s$) output file and a mass density ($\rho$) text file to calculate Gmax values (i.e., Gmax = $\rho$ $V_s^2$). The density values and Gmax values are then stored within the interval velocity file as new column entries.

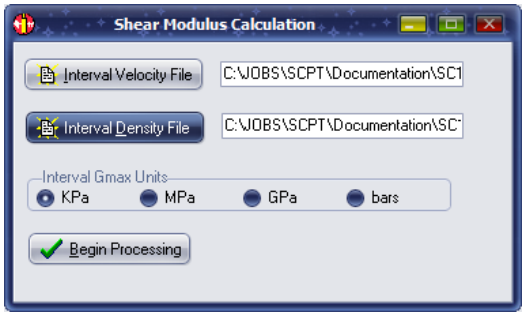



***Figure 46: Calculate Shear Modulus dialog box***

As is shown in Figure 46, the input values for the *Shear Modulus Calculation* are as follows:

1. Interval Velocity File - This is the same output file outlined in Figure 12.
2. Interval Density File - This file contains the interval mass density values as is illustrated in Figure 47. The file should be specified in column format where Depth1 (m) and Depth2 (m) are the lower and upper depth of each intervals, for which a mass density is given. The mass density values must be given in units of kg/m$^3$.
3. Interval Gmax Units - This interface allows the user to specify the units in which the Gmax values are to be stored.

| Depth1 (m) | Depth2 (m) | Density (kg/m3) |
|---|---|---|
| 1.0 | 2.0 | 1500 |
| 2.0 | 3.0 | 1600 |
| 3.0 | 4.0 | 1700 |
| 4.0 | 5.0 | 1800 |
| 5.0 | 6.0 | 1800 |
| 6.0 | 7.0 | 1850 |
| 7.0 | 8.0 | 1850 |
| 8.0 | 9.0 | 1900 |
| 9.0 | 10.0 | 1900 |

***Figure 47: Typical interval mass density text file***

After specification of the appropriate files and desired Gmax units, the user selects the *Begin Processing* push button. If the interval velocities and mass density depth increments are not synchronized, a weighted average is calculated as is illustrated in Figure 48. If the depth of the interval velocities exceeds those of the given mass densities, the deepest specified mass density value is utilized in subsequent calculations of Gmax.

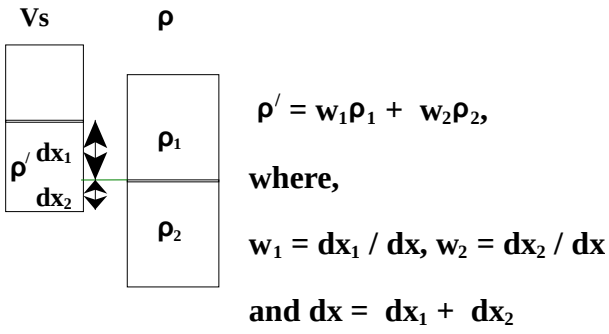



***Figure 48: Calculation of the interval mass density when the interval velocity and mass density depth increments are not synchronized***

Figure 49 shows the appended density and Gmax values of a typical interval velocity output file after implementation of the *Shear Modulus Calculation* menu option. The interval velocity file with shear modulus values appended has a name similar to the original interval velocity file name but with '_SM' appended (e.g. 'test.txt' becomes 'test_SM.txt').

2014
Project Name: Manual \ ProjectNumber: 001 \ Client: BCE
Test Number: 1 \ Location: Vancouver office \ Site Operator: GV \ Site Date: 6/26/2015 11:21:43 AM
Coordinate System: N/A \ Coordinate X: N/A \ Coordinate Y: N/A
Reference Level: N/A \ Water Level: N/A \ Ground Level: N/A

| Velocity (m/sec) | Type | Depth1 (m) | Depth2 (m) | Accuracy | Bandpass (Hertz) | density (kg/m3) | Gmax (bars) |
|---|---|---|---|---|---|---|---|
| 102.10 | S | 1.70 | 2.70 | 0.9699 | 30.0 to 100.0 | 1570.0 | 163.663 |
| 122.10 | S | 2.70 | 3.70 | 0.9693 | 30.0 to 100.0 | 1670.0 | 248.970 |
| 170.10 | S | 3.70 | 4.70 | 0.9699 | 30.0 to 100.0 | 1770.0 | 512.132 |
| 210.10 | S | 4.70 | 5.70 | 0.9693 | 30.0 to 100.0 | 1800.0 | 794.556 |
| 122.10 | S | 5.70 | 6.70 | 0.9699 | 30.0 to 100.0 | 1835.0 | 273.569 |
| 202.10 | P | 1.70 | 2.70 | 0.9699 | 110.0 to 180.0 | 1570.0 | 0.000 |
| 222.10 | P | 2.70 | 3.70 | 0.9693 | 110.0 to 180.0 | 1670.0 | 0.000 |
| 270.10 | P | 3.70 | 4.70 | 0.9699 | 110.0 to 180.0 | 1770.0 | 0.000 |
| 310.10 | P | 4.70 | 5.70 | 0.9693 | 110.0 to 180.0 | 1800.0 | 0.000 |
| 222.10 | P | 5.70 | 6.70 | 0.9699 | 110.0 to 180.0 | 1835.0 | 0.000 |

***Figure 49: Typical interval velocity output file from the Calculate Shear Modulus menu option***

# Chapter 4 View

***SC1-RAV™*** provides four advanced graphical interfaces, which allow the user to display derived interval velocities and filter and plot captured uniaxial seismic traces:

- *View Seismic Data*
- *Display VSP*
- *3D Display*
- *Display Interval Velocities*

## *4.1 View Seismic Data*

The *View Seismic Data* option allows the user to analyze an individual seismic file. Analysis features consists of filtering the seismic trace, overlaying the unfiltered trace onto the filtered trace and displaying the smoothed Fourier transform of either the unfiltered or filtered seismic time series.

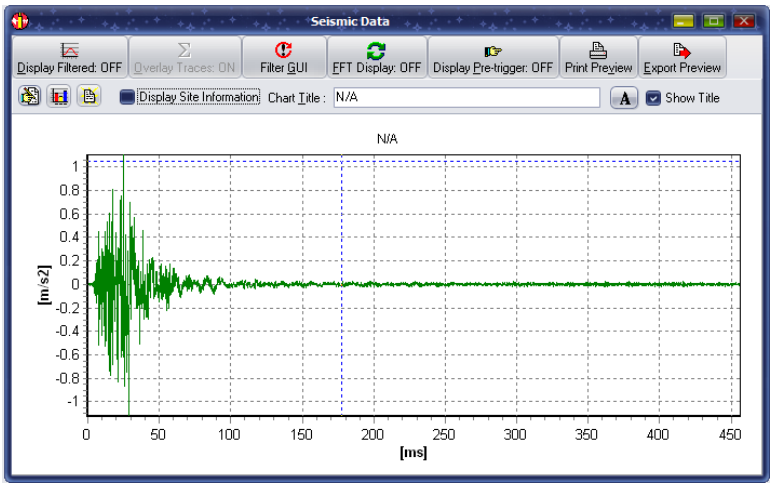



***Figure 50: Main graphical interface in View Seismic Data software option***

Upon selecting this option an input dialog box appears where the user specifies the seismic file to process. Figure 50 shows the graphical output which appears once the appropriate seismic file has been selected.

At the top of the window there is a row of buttons. The function of these buttons can be described as follows:

- Display Filtered: to display filtered traces (based upon Filter GUI parameter settings);
- Overlay Traces: to display unfiltered traces superimposed on the filtered traces;
- Filter GUI: to open the Cascadable Filters dialog box as shown in Figure 12, which allows the user to specify the filter parameters;
- FFT Display: to display the frequency spectrums of either the filtered or unfiltered traces (depending on the *Display Filtered* setting);
- Display Pre-trigger: to display the pre-trigger data;
- Print Preview: to open the Print Preview dialog box (see Figure51);
- Export Preview: to open the Export Preview dialog box (see Figure 52).

Below the row of buttons there are various checkboxes and icons:

- The *Edit Chart Settings* icon opens the dialog box shown in Figure 20, with which the chart settings can be changed; this option can also be used to export or print the chart.
- The settings can be stored by clicking on the *Save Chart Settings* icon .
- The user can also apply previously stored chart settings by clicking on the *Load Chart Settings* icon .
- The checkbox *Display Site Information* allows to user to specify whether or not the SCPT Site Information is displayed below the graphs.
- The user can specify the chart title by entering it in the box and the chart title is displayed by checking the *Show Title* box. The chart title font can be changed by clicking on the *Font* icon , which opens a dialog box (see Figure 53).

Figure 54a shows the graphical results after specifying a bandpass of 30 to 100 Hz. The user may then overlay the unfiltered seismic trace onto the filtered trace by selecting checkbox *Overlay* as illustrated in Figure 54b. The smoothed Fast Fourier Transform (FFT) of either the unfiltered or filtered seismic trace is derived and displayed by selecting checkbox *FFT*. The frequency spectrum of the filtered trace is displayed if the checkbox *Filter* is selected along with the *FFT* checkbox. Otherwise the unfiltered seismic trace's frequency spectrum is displayed. Figure 54c illustrates the frequency spectrum of the filtered data file shown in Figure 54a. Finally in Figure 54d shows the filtered trace with the pre-trigger data displayed as well.

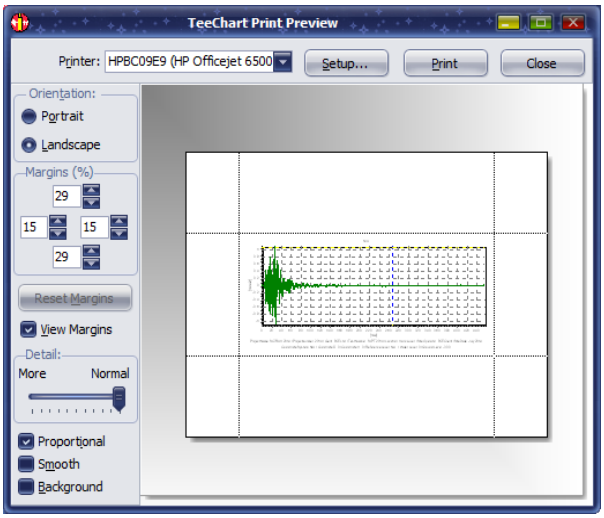



***Figure 51: Print Preview dialog box***

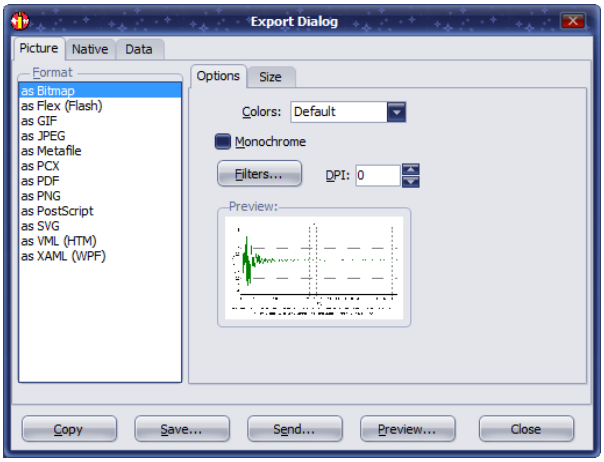



***Figure 52: Export dialog box***

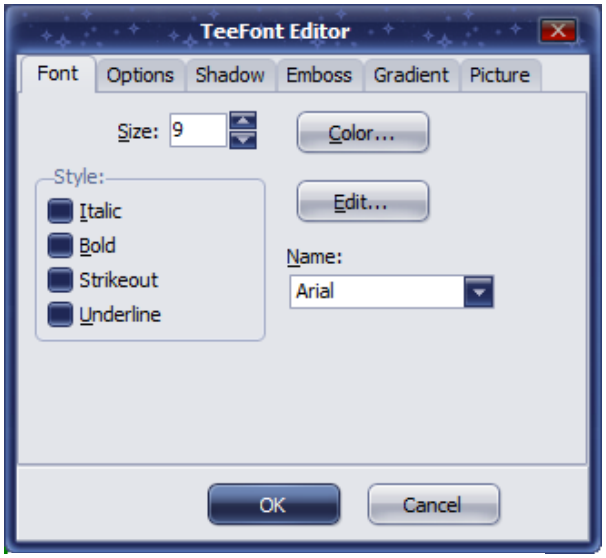



***Figure 53: Font dialog box***

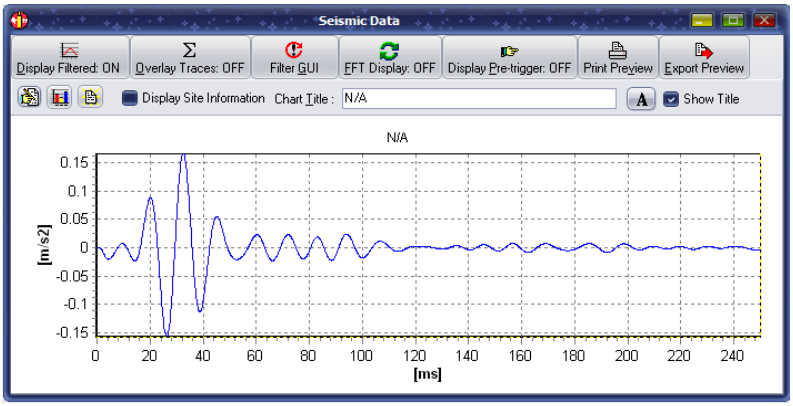
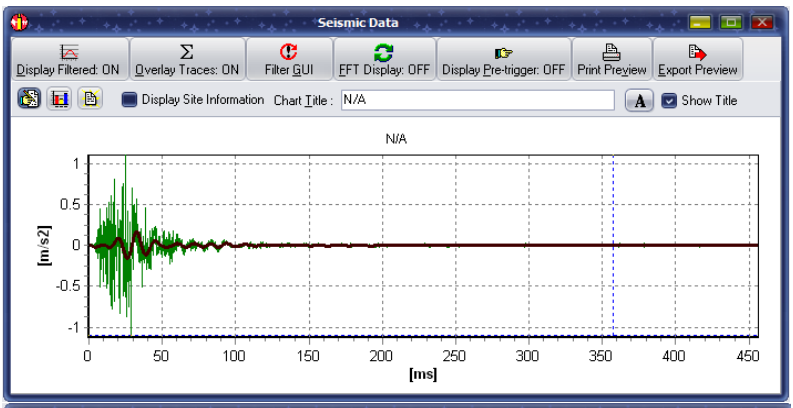
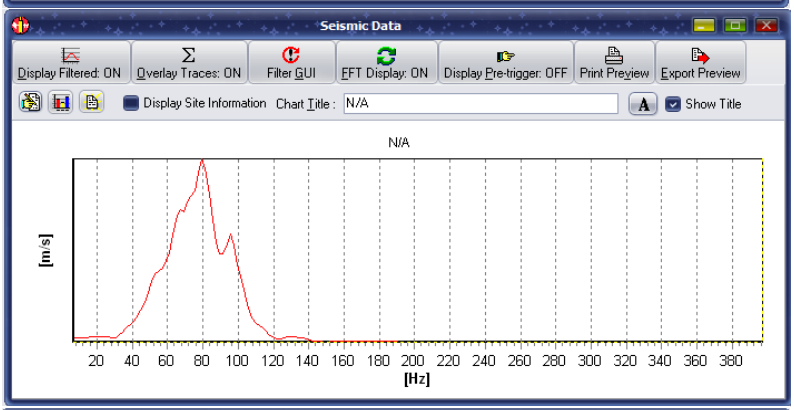



***Figure 54: Seismic trace in View Seismic Data software option***

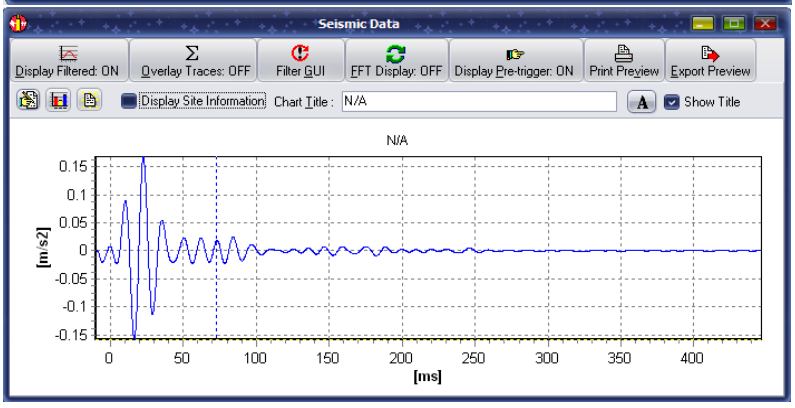
***A: filtered***




***B: Overlaying unfiltered seismic time series onto filtered time series***




***C:Frequency spectrum of seismic time series***




***D:With pre-trigger data displayed***

## 4.2 Display VSP

When the user selects the *Display VSP* option, the file input dialog box shown in Figure 55 appears. The user can input multiply seismic files in this dialog box (i.e., <SHIFT> plus left mouse click or <CTRL> plus left mouse click). After the *Open* button has been selected by the user, a vertical seismic depth profile appears as is illustrated in Figure 56.

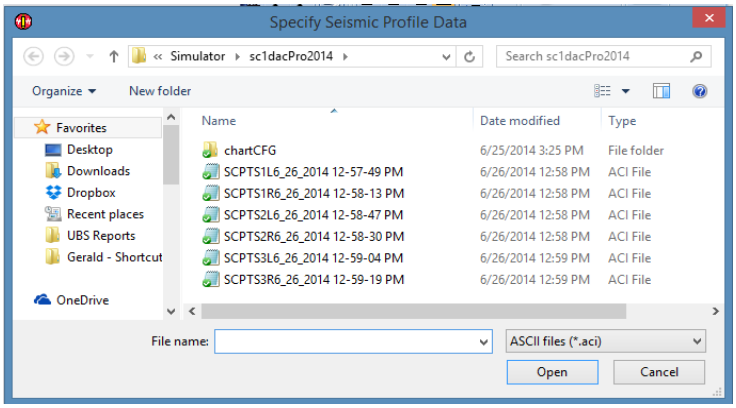



***Figure 55: Display VSP file input dialog box***

Figure 56 illustrates a typical VSP display of reversely polarized SH waves. The trend line shown in Figure 56 is specified by pressing the middle mouse button (or <shift> + right mouse button or <shift> + left mouse button) to identify individual points of interest. ***SC1-RAV™*** then automatically draws a line between the points specified and provides a velocity estimate[3]. Pressing options <Ctrl> + left mouse button or <Ctrl> + right mouse button will delete the previously specified trend line. Double clicking the middle mouse button will delete all the specified trend lines.

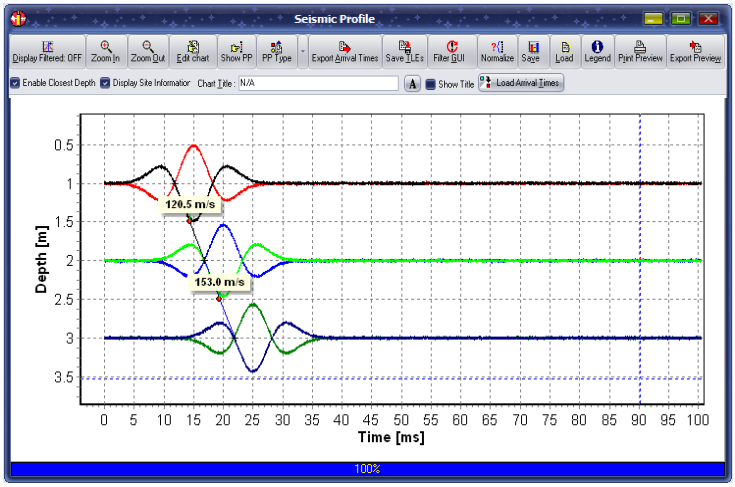



***Figure 56: Filtered (30 to 100 Hz bandpass) VSP Display seismic trace profile illustrating color coded reverse polarized waves***

As shown in Figure 56, immediately above the display there are 11 buttons to assist the user in working with this display. The function of these buttons can be described as follows:

- Display Filtered: to display filtered traces (based upon Filter GUI parameter settings);
- Zoom in: to scale the seismic amplitudes up in 10% increments;
- Zoom out: to scale the seismic amplitudes down in 10% increments;
- Edit Chart: to allow for chart formatting, printing, and exporting;
- Show PP: to enable and disable the display of peak particle values;
- PP Type: to select the peak particles values to be displayed (i.e. acceleration, velocity or displacement);

[3] To obtain accurate interval arrival times utilizing the trend line specification, it is mandatory that the user selects the appropriate time index at the exact depth of the probe from which the seismic data was recorded. Alternatively, if check box *Enable Closest Depth* is enabled the SC1-RAV software relates back to the closest data depth when specifying trend lines.

- Export Arrival Times: to allow for 1) calculating arrival times from relative arrivals and reference (to obtain true arrival times from the VSP estimated relative arrivals) 2) saving arrival times within a text file, and 3) exporting arrival times to a FMDSM database specified by the user (default name: TrendLineEst.); please note that when the box *export Calculated Arrival Times* is checked the calculated rather than the estimated relative arrivals are stored or exported.

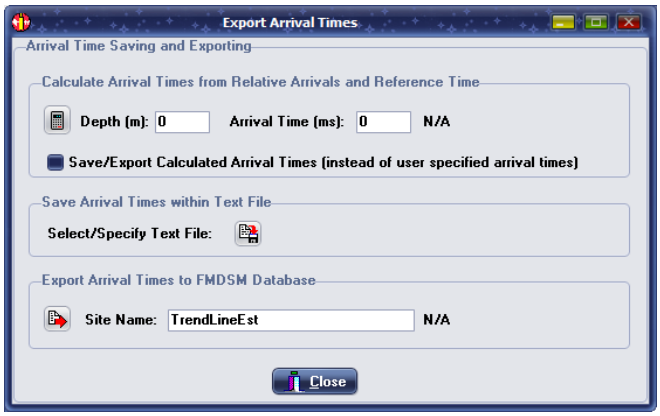

Export Arrival Times
Arrival Time Saving and Exporting
Calculate Arrival Times from Relative Arrivals and Reference Time
Depth (m): 0
Arrival Time (ms): 0
N/A
Save/Export Calculated Arrival Times (instead of user specified arrival times)
Save Arrival Times within Text File
Select/Specify Text File:
Export Arrival Times to FMDSM Database
Site Name: TrendLineEst
N/A
Close

***Figure 57: Export Arrival Times dialog box***

- Save TLEs: to save the trend line data;
- Filter GUI: to open the Cascadable Filters dialog box as shown in Figure 7, which allows the user to specify the filter parameters;
- Normalize: to normalize the displayed seismic wave traces to +/- 1.0; alternatively, the seismic amplitudes are scaled relative to the maximum amplitude within the displayed seismic profile.
- Save: to save the latest defined chart settings within the *sc1rav.ini* file for future applications;
- Normalize: to normalize the displayed seismic wave traces to +/- 1.0; alternatively, the seismic amplitudes are scaled relative to the maximum amplitude within the displayed seismic profile.
- Load: to enable the latest defined chart settings;
- Legend: to enable and disable the display of chart legend;
- Print Preview: to open the Print Preview dialog box (see Figure 51);
- Export Preview: to open the Export dialog box (see Figure 52).

Below the buttons there are two additional checkboxes:

- Enable Closest Depth: checking this box will ensure that when specifying trend lines the software will automatically matches the time selection to the closest data depth (see footnote 1);
- The checkbox *Display Site Information* allows to user to specify whether or not the SCPT Site Information is displayed below the graphs.
- The user can specify the chart title by entering it in the box and the chart title is displayed by checking the *Show Title* box. The chart title font can be changed by clicking on the *Font* icon A, which opens a dialog box (see Figure 53).
- The checkbox *Display Arrival Times* allows the user to specify a specific file with saved arrival times, which are then displayed as diamonds in the graph.

Figure 58 illustrates a VSP Display of the PPA values. As mentioned above, the display of these values can be enabled and disabled by toggling user interface button .

As the user moves the cursor over individual traces, the corresponding file name of the seismic trace is displayed at the bottom right hand corner of the chart. The user can display acceleration, velocity or displacement profiles by pressing the PP Type button and selecting the desired particle motion.

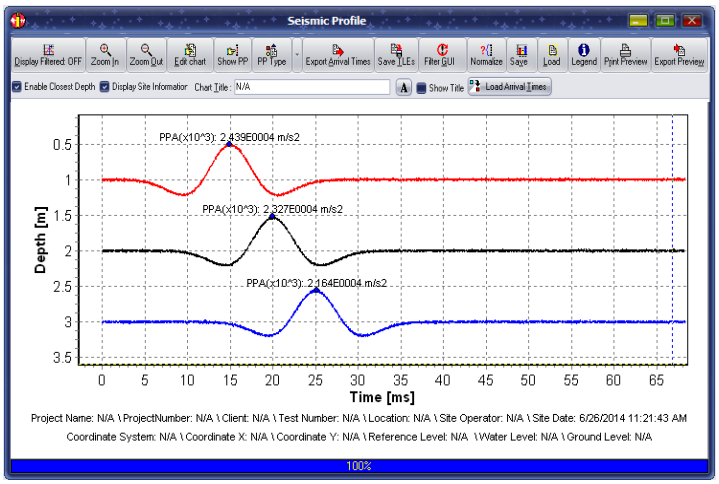



***Figure 58: Display of the PPA Values***

## 4.3 3D Display

The 3D *Display* option allows the user to display the time series data at various depths into a 3D display. In this software option the user selects the files to be displayed as previously described for the *VSP Display* options. After the *Open* button has been selected by the user, a 3*D Display* appears as is illustrated in Figure 59.

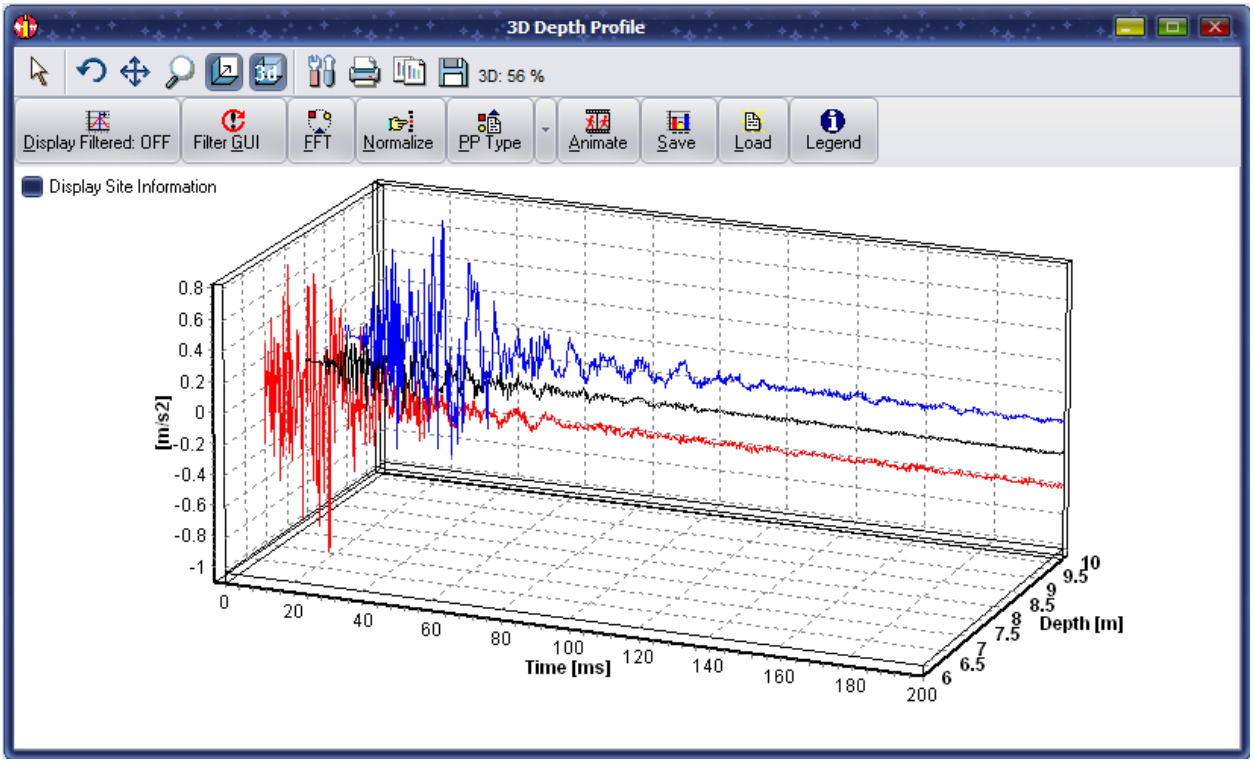



***Figure 59: Typical 3D Display (data unfiltered)***

These graphs (in the time and frequency domains ) can illustrate very well how the earth acts as a low-pass filter as the seismic source wave travels deeper into the soil stratigraphy, a phenomenon directly related to the absorption (Q value) of the soil profile.

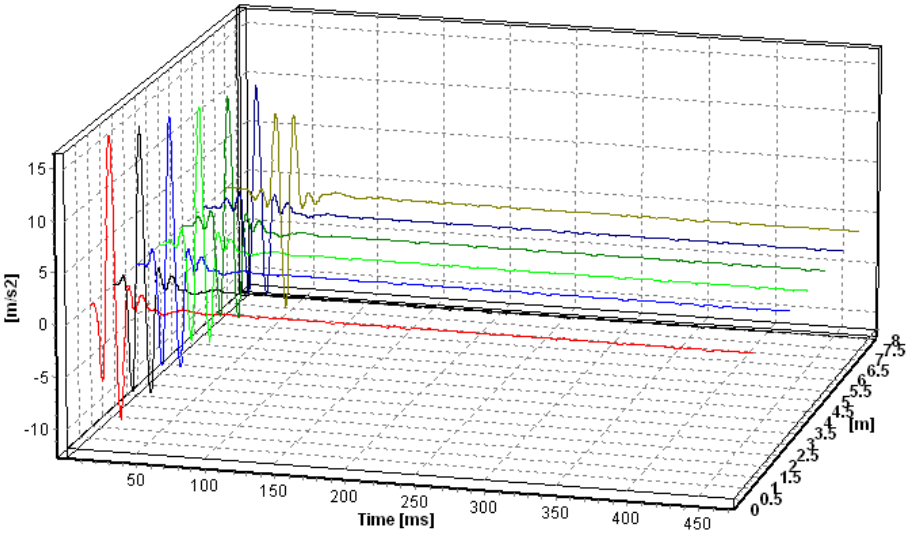



***Figure 60: Typical 3D Display (data now filtered and chart copied to clipboard as described below)***

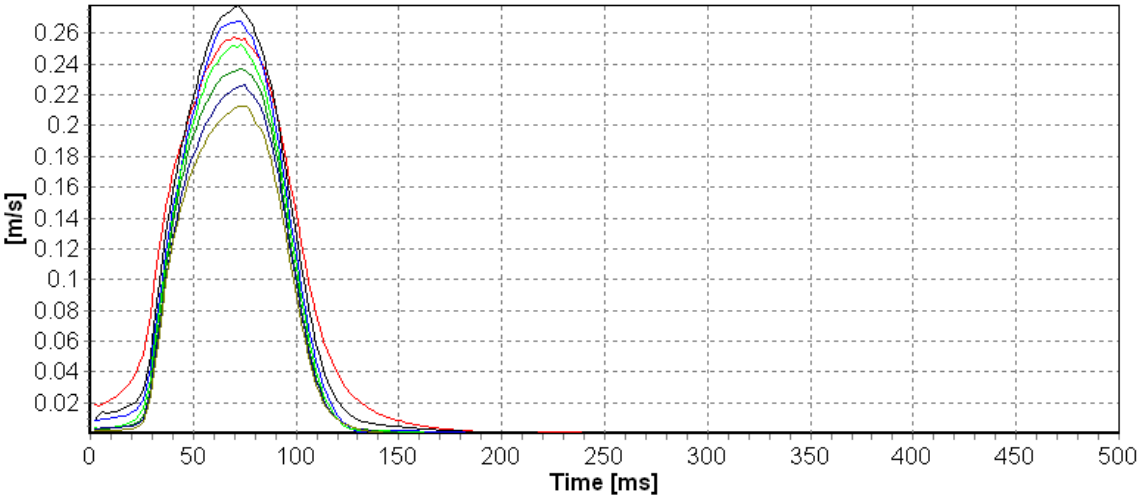



***Figure 61: 2D display of the FFT results of the filtered data shown in Figure 60)***

As shown in Figure 59, immediately above the display there are 8 buttons to assist the user in working with this display. The function of these buttons can be described as follows:

- Display Filtered: to display filtered traces (based upon Filter GUI parameter settings);
- Filter GUI: to open the Cascadable Filters dialog box as shown in Figure 7, which allows the user to specify the filter parameters;
- FFT: to derive and display the smoothed Fast Fourier Transform (FFT) of selected (filtered or unfiltered) time series data;
- Normalize: to allow normalization of the data;
- PP Type: to select whether the acceleration, velocity or displacement values of the time series data are displayed;
- Animate: to start or stop rotation of the display;
- Save: to save the latest defined chart settings;
- Load: to enable the latest defined chart settings;
- Legend: to enable and disable the display of chart legend.

Above these 8 buttons there is another toolbar with 10 options that allow the user to perform the following:

- : drag the data series with the left mouse button down to zoom , and with the right mouse button down to scroll;
- : drag the chart to rotate;
- : drag the chart to move;
- : drag the chart to zoom;
- : drag the chart to adjust the depth;
- : click to toggle between a 2D and 3D display of the data;
- : click to allow for display formatting, printing and exporting;
- : click to allow for display printing;
- : click to copy the display to the clipboard;
- : click to save the display as a TeeChart Pro file.

## 4.4 Display Interval Velocities

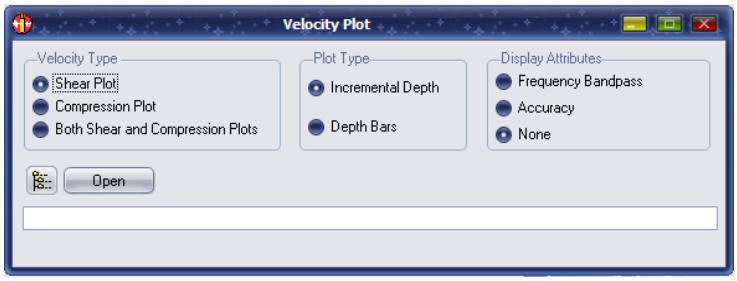



***Figure 62: Interval Velocity Display dialog box***

When the user selects the *Display Interval Velocities* option, the file input dialog box shown in Figure 62 appears. The user defines the velocity file to be displayed (either by typing in the file path and name or by clicking on the *Directory List* icon and then selecting the file from the window that opens), as well as the velocity type and plot type. Finally the user specifies whether the velocity has to be displayed by itself or together with either the frequency bandpass or the accuracy. Once the required entries have been made the user clicks the *Open* button to generate a graph similar to Figure 63.

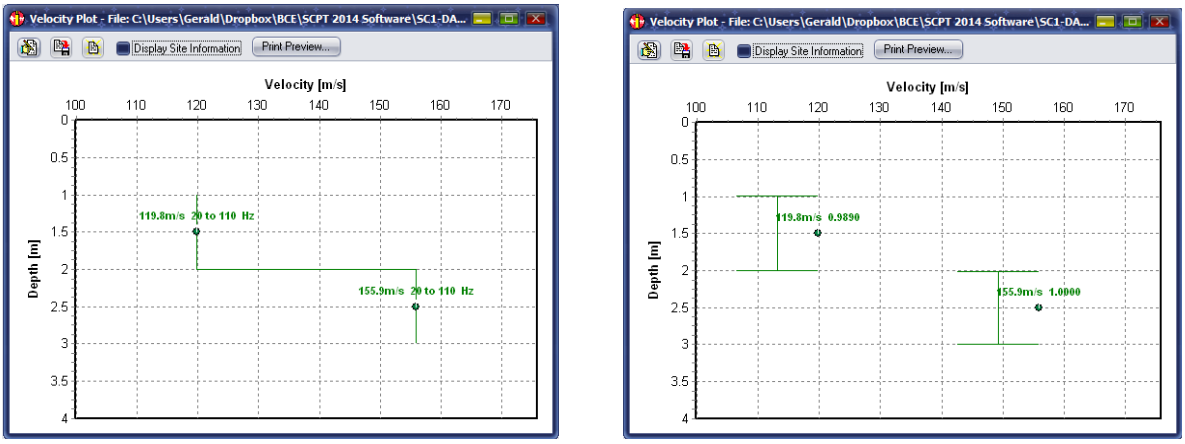



***Figure 63: Interval Velocity Display (incremental depth with frequency bandpass information on the left, depth bars with accuracy on the right)***

At the top of this figure there are various checkboxes and icons:

- The *Edit Chart Settings* icon opens the dialog box shown in Figure 69, with which the chart settings can be changed; this option can also be used to export or print the chart.
- The settings can be stored by clicking on the *Save Chart Settings* icon
- The user can also apply previously stored chart settings by clicking on the *Load Chart Settings* icon
- Clicking the *Print Preview* button opens the dialog box shown in Figure 70, with which the chart can be printed.
- The checkbox *Display Site Information* allows to user to specify whether or not the SCPT Site Information is displayed below the graphs.

# Chapter 5 Utilities

As shown in Figure 64, the *Utilities* menu has 3 different options:

- *Default Graphical User Interface (GUI) Settings*
- *Sensor Type and Units*
- *Sort SH Data Files and Create Working Directories.*

***Figure 64: Utilities Menu***

## *5.1 Default GUI Settings*

The *Default GUI Settings* dialog box is shown in Figure 65. Here the user can specify the minimum and maximum frequency axis values, as well as the precision, the number of digits and the increment for both the vertical amplitude axis and the horizontal time axis.

The minimum and maximum frequency axis values are used for the *Cross-correlation->Manual Filtering* frequency display and the *View->Seismic Data* frequency display. The default settings for these frequencies are zero and the Nyquist frequency ($1/2\Delta$, where $\Delta$ is the sampling rate) respectively. If the user wishes to change these values, then check box *Enable* should be checked and the appropriate minimum and maximum frequencies should be specified.

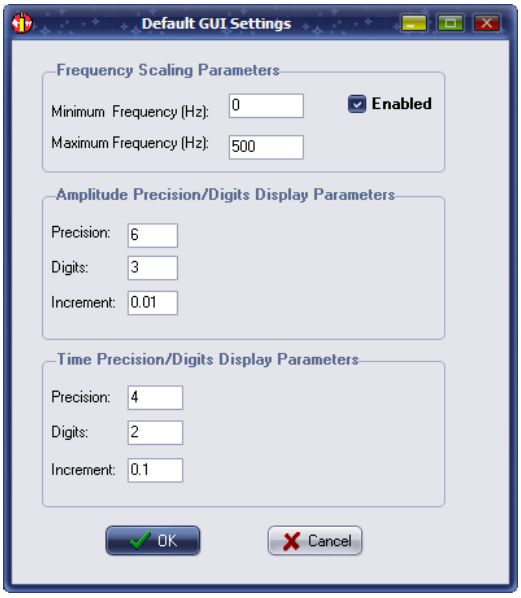



***Figure 65: Default GUI Settings***

The precision, the number of digits and the increment for both the vertical amplitude axis and the horizontal time axis are used for all charts displayed within ***SC1-RAV™***. These settings are then stored within configuration file *sc1rav.ini* so that they will be implemented whenever ***SC1-RAV™*** is used.

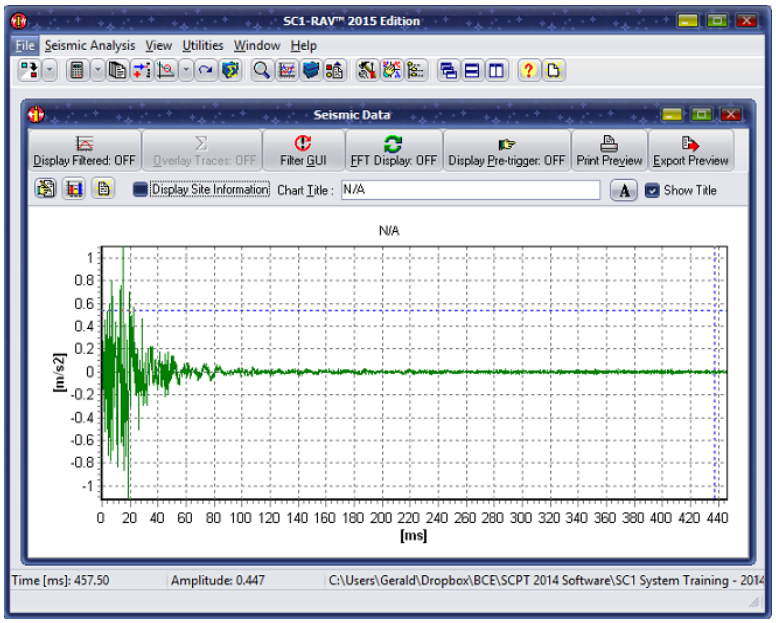



***Figure 66: View->Seismic Data display with the Amplitude and Time default settings (Precision, Digits and Increment) set at 6, 3, 0.01 and 4, 2, 0.1, respectively.***

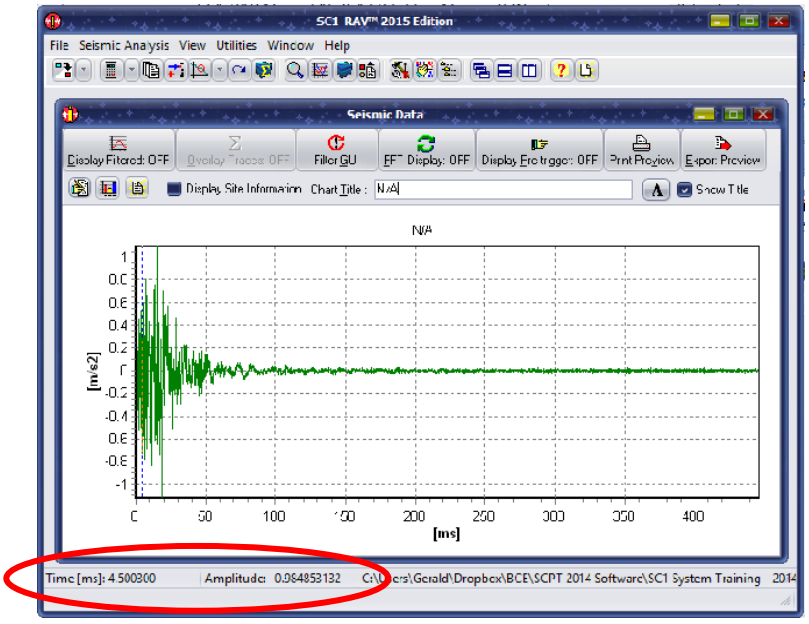



***Figure 67: View->Seismic Data display with the Amplitude and Time default settings (Precision, Digits and Increment) set at 9, 9, 0.00001 and 6, 6, 0.00001, respectively.***

## 5.2 Sensor Type and Units

The *Sensor Type and Units* dialog boxes are shown in Figure 68. The *Sensor Type Specification* interface allows the user to specify whether an *Accelerometer* (output proportional to particle acceleration) or a *Geophone* (output proportional to particle velocity) is used. This selection should be made prior to any analysis or displays described in Sections 3.0 and 4.0. The *Desired Units* user interface facilitates the specification of whether the particle velocities and accelerations recorded are given in units of m/s and $m/s^2$ or mm/s and $mm/s^2$, respectively.

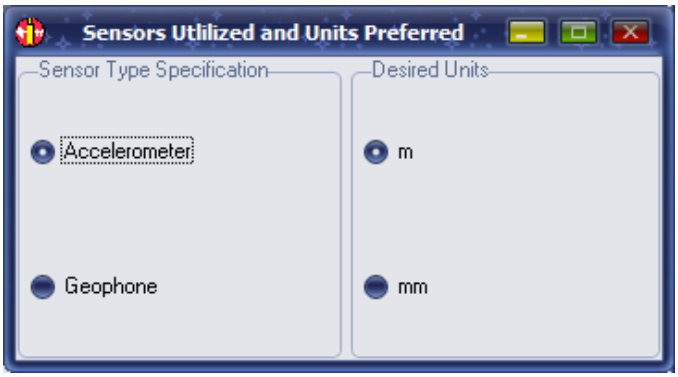



***Figure 68: Sensor Type and Units dialog boxes***

## 5.3 Sort SH Data Files and Create Working Directories

Within this Utilities option the user can automatically create all necessary SH-wave working directories. When this software option is a selected a standard file open dialog box is displayed as shown in Figure 69, where the user can navigate to the directory where the seismic data resides, select all acquired seismic data files for a specific DST or SCPT profile, and then press interface button "Open".

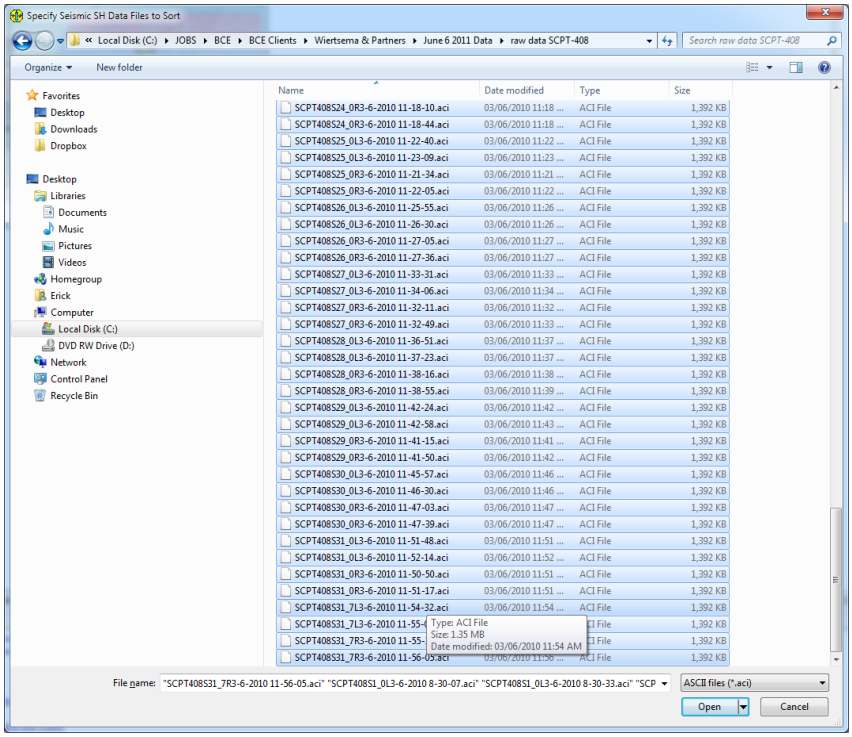



***Figure 69: User interface dialog box for selecting files to be sorted.***

*SC1-RAV*™ will then create the following subdirectories:

'...\Left Side\';
'...\Right Side\';
'...\Reverse Polarity\';
'...\SCPT Results\';

If the *SC1-DAC*™ automatic file naming convention was used for the raw seismic data files, the files are then also automatically moved to the appropriate directory

If multiple "Stacked" files were acquired and saved at each depth interval it is recommended that the user selects only the latest saved trace. This will save significant time in post processing.

# Chapter 6 Chart Formatting, Exporting, and Printing

The graphical edit button displayed in various screens allows for chart formatting, printing, and exporting. Figure 70 illustrates the graphical interface that appears when this button is selected, which allows for extensive modification of the displayed data and chart attributes. In addition the data can be printed by selecting the *Print* tab, which brings up the *Chart Printing Dialog Box* as shown in Figure 71. Finally, this utility has an extensive electronic Help function, which is accessed though the H*elp* button at the bottom left of the screen.

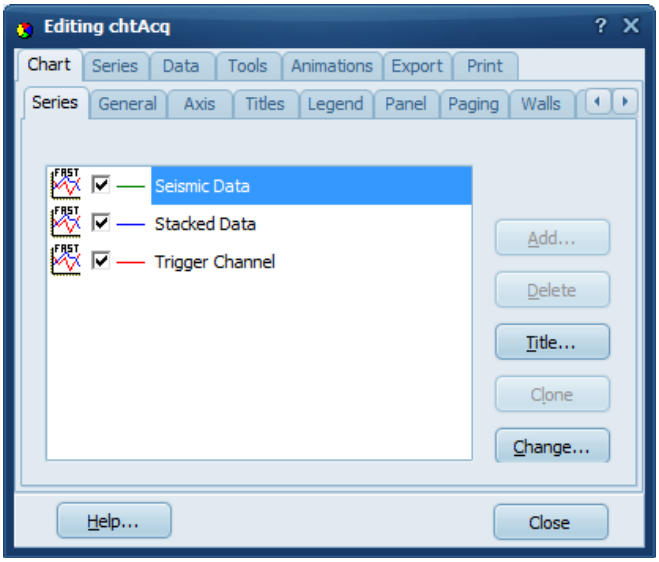



***Figure 70: Chart Editing Dialog Box***

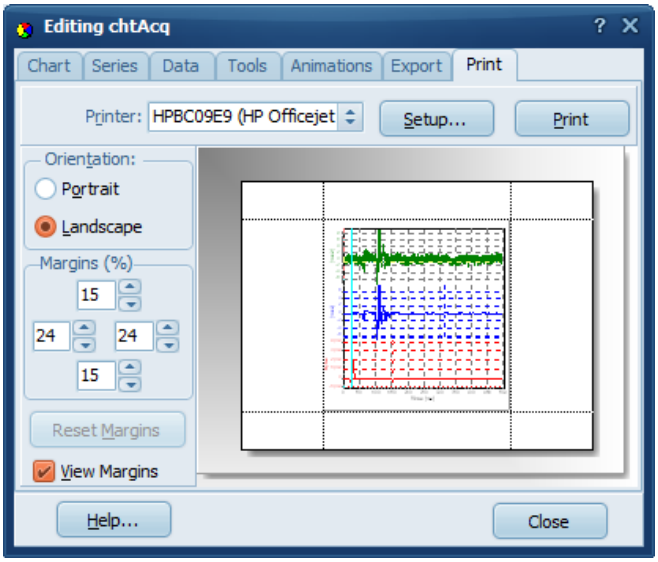



***Figure 71: Chart Printing Dialog Box***

# Chapter 7 Window Submenu Options

The Window option provides the user with 4 options to arrange the open window(s):

- Cascade
- Tile Horizontally
- Tile Vertically
- Minimize All

# Chapter 8 Help Submenu Options

The Help option provides the user with 3 options:

- About - provides software version information on ***SC1-RAV™***.
- User's Manual - will output the ***SC1-RAV™*** user's manual in a default pdf browser.
- Appendix 1 - will output the paper included in Appendix 1 of this manual in a default pdf browser.
- Appendix 2 - will output the paper included in Appendix 2 of this manual in a default pdf browser
- Link to BCE - makes a link to Baziw Consulting Engineers' web page.

# Appendix 1 - Baziw, E.J. 1993. Digital filtering techniques for interpreting seismic cone data. Journal of Geotechnical Engineering, Vol. 119 No. 6 ASCE. 98-1018.

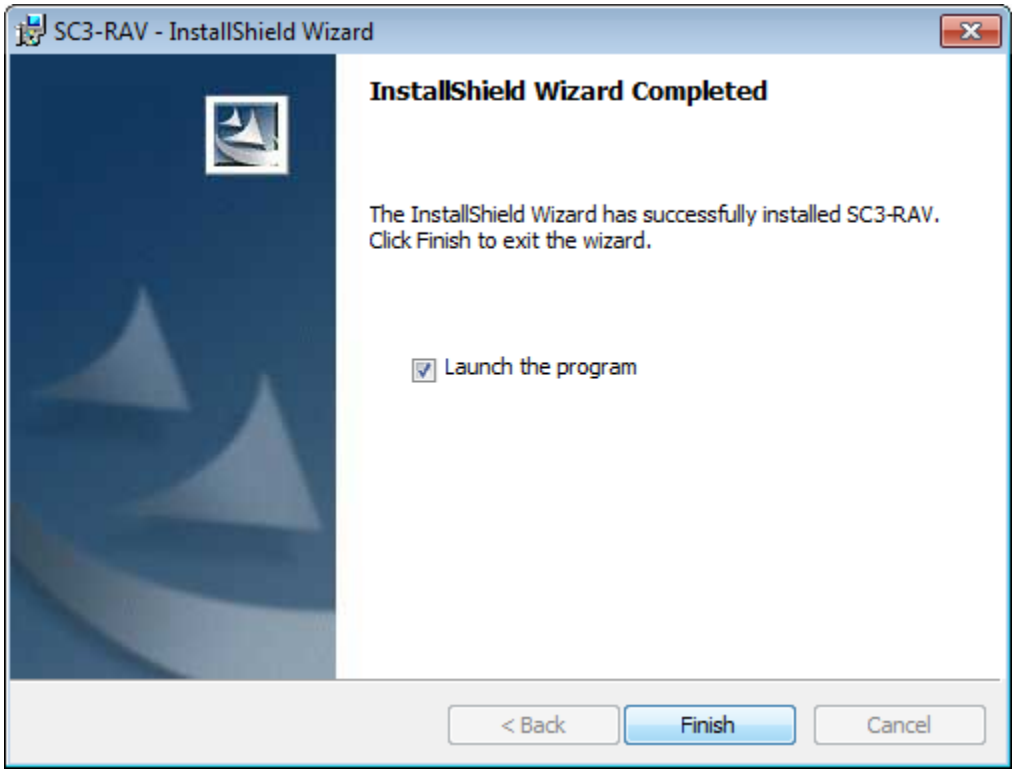
# Appendix 2 - Baziw, E.J. 2002. Derivation of seismic cone interval velocities utilizing forward modeling and the downhill simplex method. Can. Geotech. J., vol. 39, pp.1-12.

# Appendix 3 - SC1-RAV™ 2015 Installation Procedure

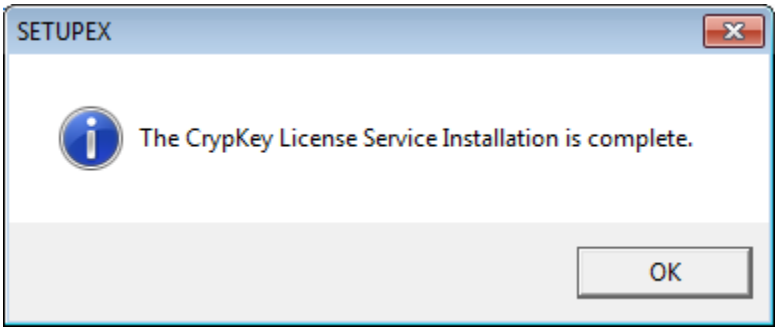
***STEP 1:***

Run setup.exe as an administrator.

When the screen below appears – leave "Launch the program" checked. This will allow for the CrypKey drivers to be automatically installed.

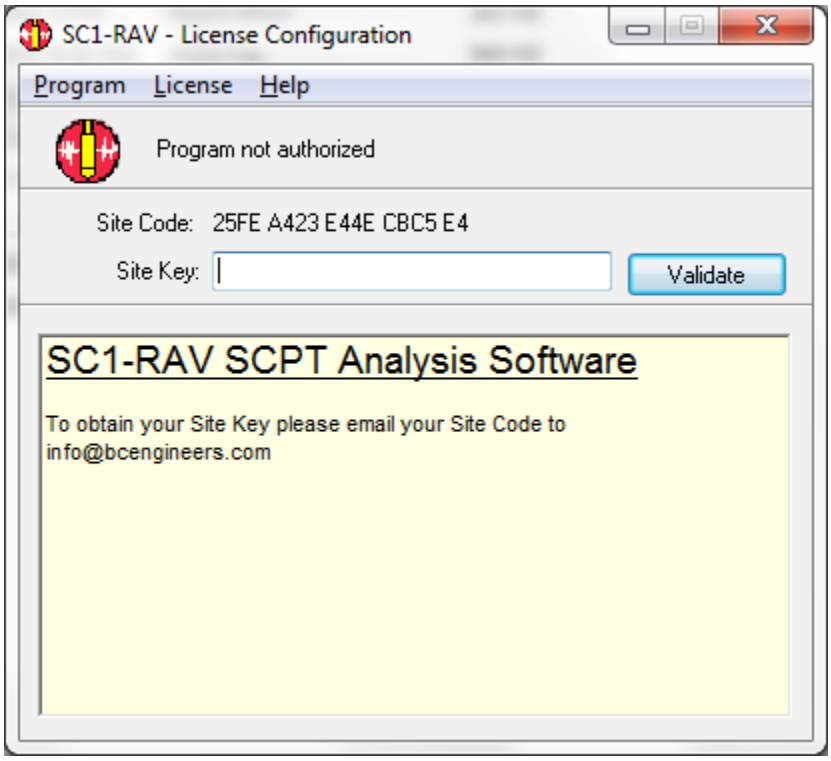



Upon Installation of the CrypKey drivers the screen below appears.



***STEP 2 (Obtain Site Key for SC1-RAV):***

Run SC1-RAV™ as an administrator. On the first execution of SC1-RAV™ the interface below appears. Email (cut and paste) BCE the Site Code (e.g., "25FE A423 E44E CBC5 E4"). BCE email will then email the required Site Key for validation.



# Appendix 4 USB Flash Drive License Transfer Procedure

This type of operation transfers a license from an existing authorized copy of an application on one computer to an unauthorized copy of the product on a second computer. The transfer process does not jeopardize your license in any way and is completely secure because the USB Flash Drive is registered to a specific PC in a specific location. This ensures the license can only be transferred to the target PC you specify.

***Please note where the software shows "floppy drive" a USB flash drive can be used as the medium instead.***

The procedure is illustrated by the transfer of the *Calculator* example program from PC-1 to PC-2.

***STEP 1***

Ensure that you have an authorized copy of the application on PC-1, an unauthorized copy of the application on PC-2, and a USB Flash Drive inserted into PC-2.

***STEP 2***

Your first operation is on the *unauthorized* computer (i.e., PC-2).Start the program on PC-2. The program's opening window is shown below:

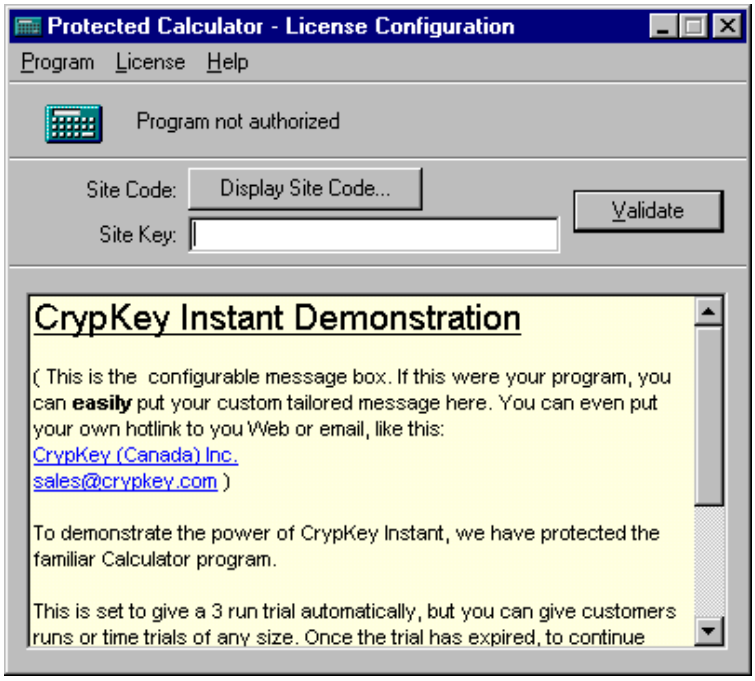

Protected Calculator - License Configuration
Program License Help
Program not authorized
Site Code:
Display Site Code...
Validate
Site Key:
CrypKey Instant Demonstration
( This is the configurable message box. If this were your program, you can easily put your custom tailored message here. You can even put your own hotlink to you Web or email, like this:
CrypKey (Canada) Inc.
sales@crypkey.com )
To demonstrate the power of CrypKey Instant, we have protected the familiar Calculator program.
This is set to give a 3 run trial automatically, but you can give customers runs or time trials of any size. Once the trial has expired, to continue

**Figure 1: Unauthorized Program running on PC-2**

***STEP 3***

In the above window, click the License option to display the Transfer in from another computer command, as shown in Figure 2 below; after that the system shows the window shown in Figure 3.

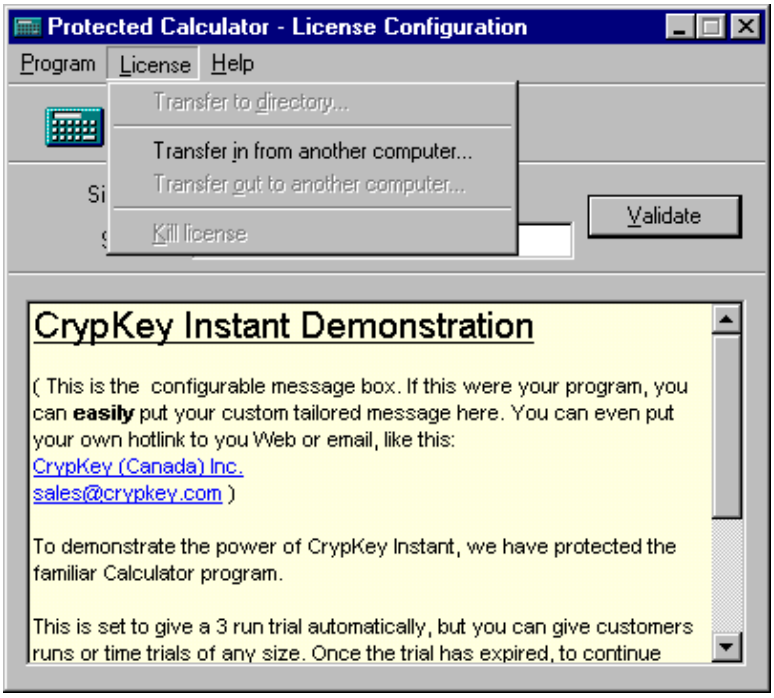

Protected Calculator - License Configuration
Program
License
Help
Transfer to directory...
Transfer in from another computer...
Transfer out to another computer...
Kill license
Validate
CrypKey Instant Demonstration
( This is the configurable message box. If this were your program, you can easily put your custom tailored message here. You can even put your own hotlink to you Web or email, like this:
CrypKey (Canada) Inc.
sales@crypkey.com )
To demonstrate the power of CrypKey Instant, we have protected the familiar Calculator program.
This is set to give a 3 run trial automatically, but you can give customers runs or time trials of any size. Once the trial has expired, to continue

**Figure 2: "Transfer in…" Command**

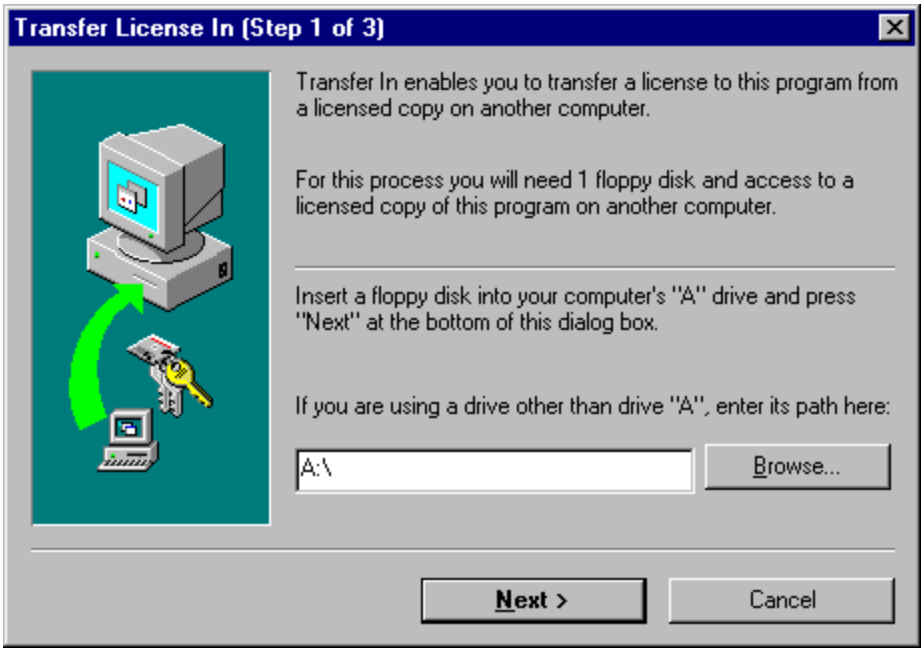

Transfer License In (Step 1 of 3)
Transfer In enables you to transfer a license to this program from a licensed copy on another computer.
For this process you will need 1 floppy disk and access to a licensed copy of this program on another computer.
Insert a floppy disk into your computer's "A" drive and press "Next" at the bottom of this dialog box.
If you are using a drive other than drive "A", enter its path here:
A:\
Browse...
Next >
Cancel

**Figure 3: "Transfer License In" Window (Step 1)**

***STEP 4***

In the above window, use the **Browse** button if necessary to supply the USB Flash Drive path, then click **Next**. The program imprints its registration on the USB Flash Drive and the system displays the following window:

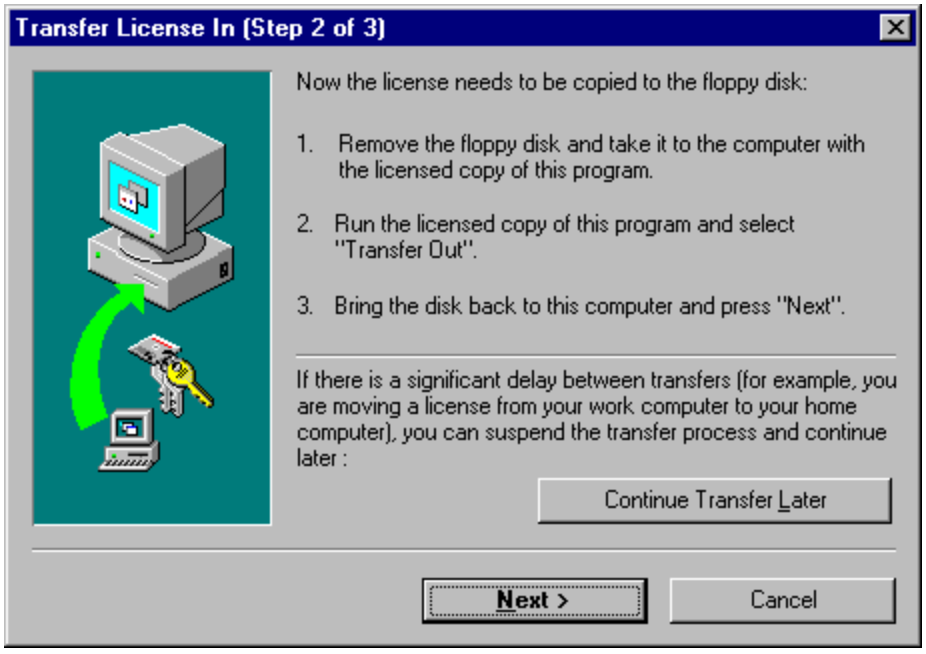

Transfer License In (Step 2 of 3)
Now the license needs to be copied to the floppy disk:
1. Remove the floppy disk and take it to the computer with the licensed copy of this program.
2. Run the licensed copy of this program and select "Transfer Out".
3. Bring the disk back to this computer and press "Next".
If there is a significant delay between transfers (for example, you are moving a license from your work computer to your home computer), you can suspend the transfer process and continue later :
Continue Transfer Later
Next >
Cancel

**Figure 4: "Transfer License In" Window**

***STEP 5***

If you need to close the PC-2 program while you work with the PC-1 program, click the **Continue Transfer Later** button in the above window. The system displays the following popup message:

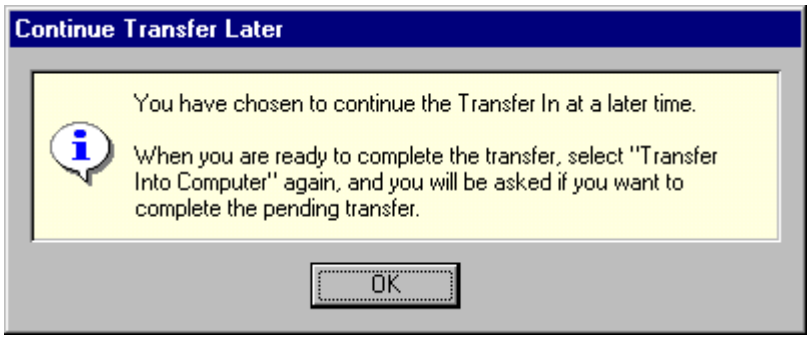

Continue Transfer Later
You have chosen to continue the Transfer In at a later time.
When you are ready to complete the transfer, select "Transfer Into Computer" again, and you will be asked if you want to complete the pending transfer.
OK

Figure 5: Continue Transfer Later Popup Window

***STEP 6***

Click **OK** to acknowledge the above popup.

***STEP 7***

Remove the USB Flash Drive from PC 2, and insert it into PC 1. Start the program on PC 1, and when the BCE flash screen appears hit the space bar. This will open the License Configuration Manager; click the **License** button as shown below:

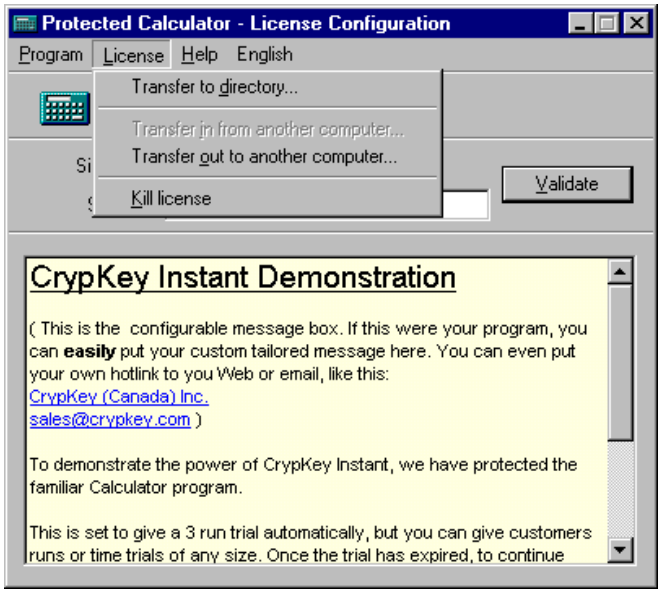

Protected Calculator - License Configuration
Program
License
Help
English
Transfer to directory...
Transfer in from another computer...
Transfer out to another computer...
Kill license
Validate
CrypKey Instant Demonstration
( This is the configurable message box. If this were your program, you can easily put your custom tailored message here. You can even put your own hotlink to you Web or email, like this:
CrypKey (Canada) Inc.
sales@crypkey.com )
To demonstrate the power of CrypKey Instant, we have protected the familiar Calculator program.
This is set to give a 3 run trial automatically, but you can give customers runs or time trials of any size. Once the trial has expired, to continue

**Figure 6: Program on PC-1: "Transfer Out" Command**

***STEP 8***

In the above window, click the Transfer out to another computer option. The system displays the following window:

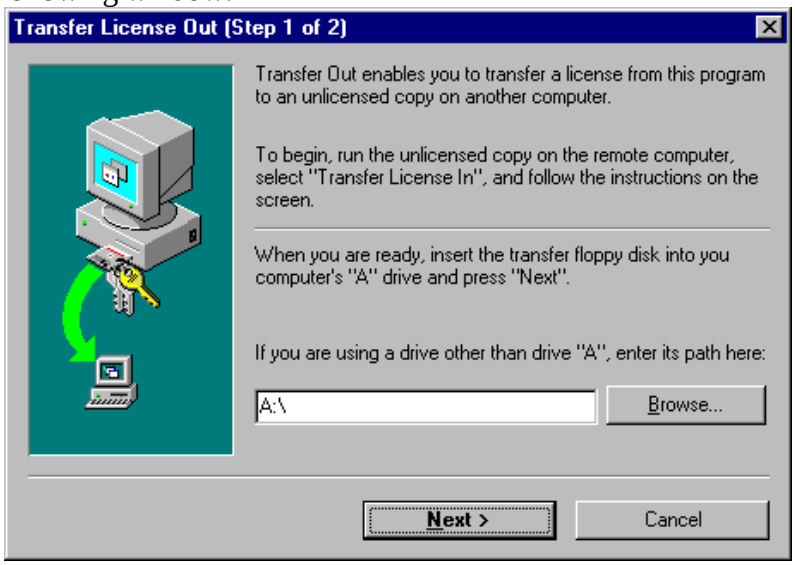

Transfer License Out (Step 1 of 2)
Transfer Out enables you to transfer a license from this program to an unlicensed copy on another computer.
To begin, run the unlicensed copy on the remote computer, select "Transfer License In", and follow the instructions on the screen.
When you are ready, insert the transfer floppy disk into you computer's "A" drive and press "Next".
If you are using a drive other than drive "A", enter its path here:
A:\
Browse...
Next >
Cancel

***Figure 7: "Transfer License Out" Window***

***STEP 9***

In the above window, use the **Browse** button if necessary to supply the USB Flash Drive path, then click **Next**. The program reads the registration imprint file and then writes a matching file to the USB Flash Drive, decrementing the license count at the source or discontinuing it (if it is a single user license).

***STEP 10***

Remove the USB Flash Drive from PC-1, and return it to PC 2.

***STEP 11***

Resume the program on PC-2.

- If you did **not** exit from the program in Step 5, proceed to Step 13.
- If you exited the program in Step 5, the following window appears when you start the program again:

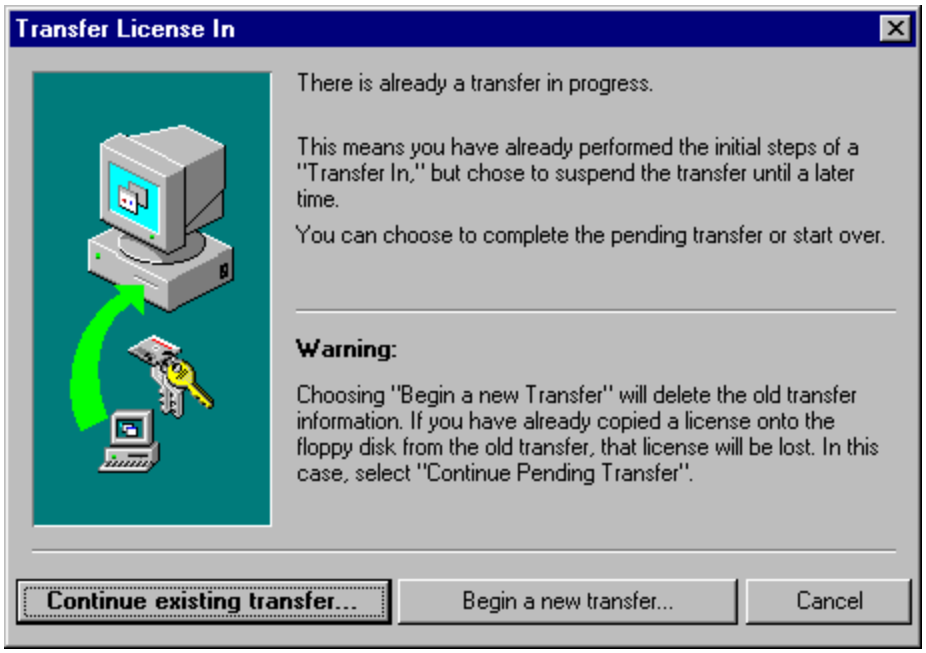

Transfer License In
There is already a transfer in progress.
This means you have already performed the initial steps of a "Transfer In," but chose to suspend the transfer until a later time.
You can choose to complete the pending transfer or start over.
Warning:
Choosing "Begin a new Transfer" will delete the old transfer information. If you have already copied a license onto the floppy disk from the old transfer, that license will be lost. In this case, select "Continue Pending Transfer".
Continue existing transfer...
Begin a new transfer...
Cancel

**Figure 8: Transfer in Progress Window**

***STEP 12***

The above window simply advises you that you have previously initiated a license transfer. To continue this operation, click Continue existing transfer in the above window. The following window is displayed:

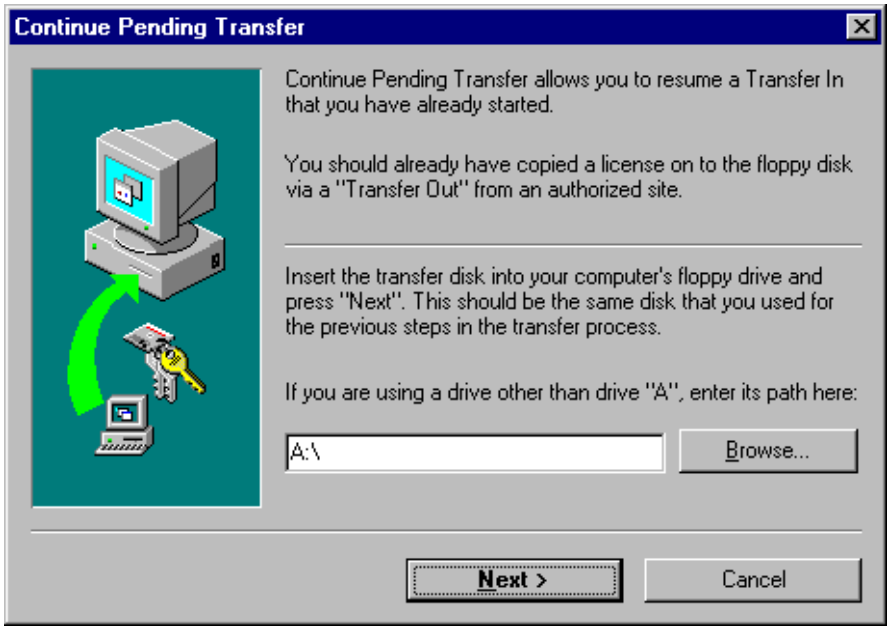

Continue Pending Transfer
Continue Pending Transfer allows you to resume a Transfer In that you have already started.
You should already have copied a license on to the floppy disk via a "Transfer Out" from an authorized site.
Insert the transfer disk into your computer's floppy drive and press "Next". This should be the same disk that you used for the previous steps in the transfer process.
If you are using a drive other than drive "A", enter its path here:
A:\
Browse...
Next >
Cancel

***Figure 9: Continue Pending Transfer Window***

***STEP 13***

If you did **not** exit the program on PC-2, the program window appears as follows:

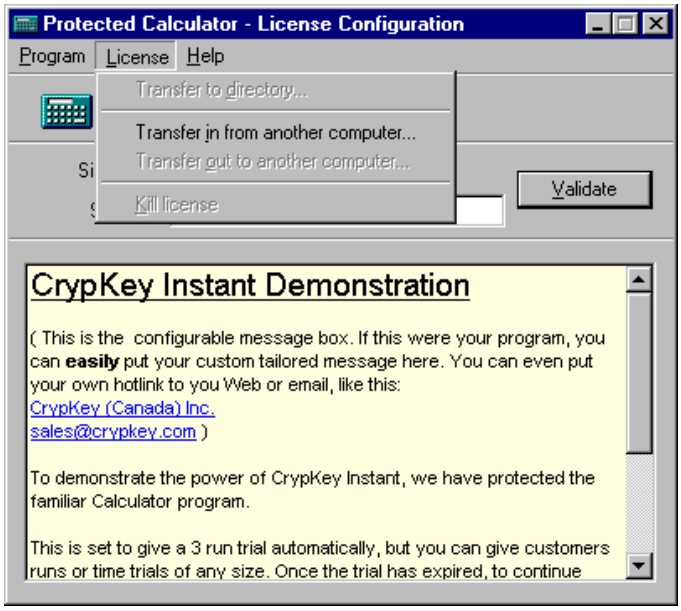

Protected Calculator - License Configuration
Program
License
Help
Transfer to directory...
Transfer in from another computer...
Transfer out to another computer...
Kill license
Validate
CrypKey Instant Demonstration
( This is the configurable message box. If this were your program, you can easily put your custom tailored message here. You can even put your own hotlink to you Web or email, like this:
CrypKey (Canada) Inc.
sales@crypkey.com )
To demonstrate the power of CrypKey Instant, we have protected the familiar Calculator program.
This is set to give a 3 run trial automatically, but you can give customers runs or time trials of any size. Once the trial has expired, to continue

***Figure 10: Window resuming operation of program on PC-2***

In the above window, click **Transfer Into Computer** to complete the transfer. The system displays the Continue Pending Transfer window, shown in Figure9.

***STEP 14***

Click **Next** in the Continue Pending Transfer window. The following window appears, indicating that the transfer is complete:

***Figure 11: "Transfer License In" Window***

***STEP 15***

Click **Finish**. The License Configuration window on PC-2 appears, showing that you are authorized to use the software.

# Appendix 5 - License Removal Procedure

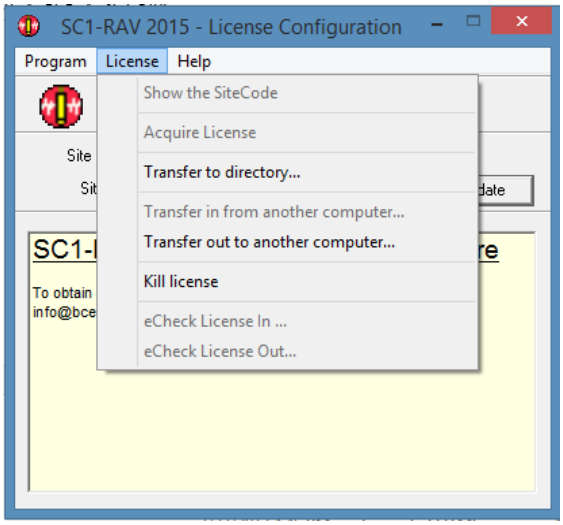
In certain cases (e.g. when obtaining a software upgrade) it may be necessary to demonstrate that the current license is removed. The procedure to do this is as follows:

***STEP 1***

Execute software and then press 'space bar' during start-up.

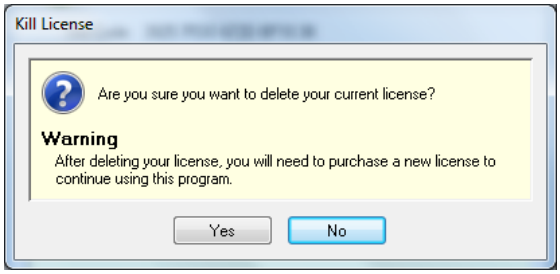
***STEP2***

Select *Kill License* as shown below.



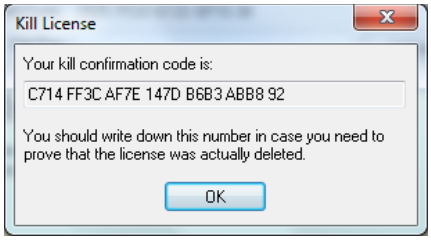

***STEP 3***

State *Yes* to message below to "kill" the current license.


Kill License
Are you sure you want to delete your current license?
Warning
After deleting your license, you will need to purchase a new license to continue using this program.
Yes
No

***STEP 4***

Email BCE the screen capture of *confirmation code* as shown below.


Kill License
Your kill confirmation code is:
C714 FF3C AF7E 147D B6B3 ABB8 92
You should write down this number in case you need to prove that the license was actually deleted.
OK